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A CONTRIBUTION TO THE LIFE HISTORY OF THE NOMEID FISH *PSENES CYANOPHYRS* CUVIER AND VALENCIENNES.¹

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ABSTRACT

Thirty postlarval, juvenile and adult specimens of *Psenes cyanophrys* Cuvier and Valenciennes, ranging from 2.5 to 66.0 mm standard length, from the Straits of Florida and the Caribbean Sea, are described and six are illustrated. Changes during development, spawning and spawning areas, and general biology are discussed.

INTRODUCTION

The most common nomeid fish taken in surface hauls in Florida and Caribbean waters is *Psenes cyanophrys* Cuvier and Valenciennes. The present work is confined to the study of a series of 30 postlarval and juvenile specimens of this species contained in the collections of the Marine Laboratory of the University of Miami. This paper is one of a series published as results of investigations carried out since 1953 by the National Geographic Society—Marine Laboratory, University of Miami, Pelagic Fish Life History program under the direction of Dr. Gilbert L. Voss.

The author wishes to thank the National Geographic Society for the financial assistance which made this work possible and the Marine Laboratory for the facilities and specimens placed at her disposal. She is deeply grateful to Dr. Gilbert L. Voss for his supervision and guidance in the course of this study, and to Dr. C. P. Idyll, Dr. Hilary B. Moore, and Mr. Luis R. Rivas for their valuable criticisms and suggestions. In addition she wishes to thank the captain and crew of the research vessel *PHYSALIA* for the collection of the material used in this study and Mrs. Nancy A. Voss and Mrs. Joan F. Clancey for sorting the larvae to family. Finally she wishes to

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thank Dr. Leonard P. Schultz, Curator of Fishes, United States National Museum, for reading the manuscript and for his valuable criticisms and suggestions. This work was carried out under a Fulbright Fellowship while the author was on leave of absence from the Bureau of Fisheries, Philippine Government.

MATERIALS, METHODS AND TERMINOLOGY

The majority of the specimens were obtained from the surface by means of dip nets and plankton nets at stations (Table 1) in the

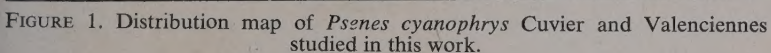
TABLE 1

STATION DATA OF THIRTY POSTLARVAL AND JUVENILE SPECIMENS OF *Psenes cyanophrys* CUVIER AND VALENCIENNES.

Station	Date	Time	Location	Depth M	Temp. °C	Sal. ‰	No. of specimens
10	4/ 2/54	0300	23°49'N, 82°31'W	0	27.10	— —	6
74	4/11/54	1610	18°34'N, 82°04'W	0	27.50	36.11	1
79	4/12/54	0100	18°04'N, 82°41'W	0	26.67	36.13	1
84	4/12/54	0845	17°39'N, 83°12'W	0	28.00	34.83	3
89	4/12/54	1700	17°14'N, 83°49'W	0	27.40	36.24	10
SL14 B-0	3/19/53	2100	25°35'N, 79°25'W	0	26.64	35.92	1
SL14 C-0	3/20/53	0055	25°35'N, 79°25'W	0	26.64	35.92	1
SL18 B-0	7/12/53	0220	25°35'N, 79°25'W	0	28.08	— —	1
SL19 B-0	8/14/53	2050	25°35'N, 79°25'W	0	29.82	36.41	1
SL20 A-0	10/5/55	0430	10 mi. E. of Miami	0	28.80	— —	1
NG32-39	8/15/51	0810	26°08'N, 79°56'W	0	— —	— —	2

Caribbean Sea, off Grand Cayman, and in the Straits of Florida (Figure 1) during an oceanographic survey of the area by the Marine Laboratory vessel *PHYSALIA* in connection with the Laboratory's Tropical Oceanography contract with the Office of Naval Research. The remaining material was taken from two routine stations in the Florida Current off Miami by the same vessel in the course of the fish larvae work and in conjunction with an earlier plankton investigation. The location occupied as the first routine station designated NG was about ten miles east of the Miami sea buoy on the west side of the Florida Current (25°53' to 26°08'N, 79°56'W) where the depth is over 100 fathoms. The other routine station designated SL was located on the east side of the Florida Current where there is an average depth of 740 meters.

A description of the nets, number of hauls at each station, the hydrographic instruments used, and the methods of handling the collections has been given by N. Voss (1954). Complete data for



the stations in the lower Straits of Florida and the Caribbean Sea have been given by Hela *et al* (1955), and for the NG stations by Miller *et al* (1953).

The terms LARVA, PROLARVA, POSTLARVA and JUVENILE are used as defined by Hubbs (1943). All illustrations are by the author.

MEASUREMENTS, PROPORTIONS AND COUNTS

The smaller specimens, up to 9.4 mm, were measured with a micrometer eyepiece and the larger ones with a pair of dividers. Unless destroyed, the left side was used to make the counts and the lateral measurements. Total length, which has no apparent value in this study, was not taken.

The definitions of measurements herein used were adapted from Voss (1954) all of which suited the present specimens. STANDARD LENGTH, in smaller specimens before the appearance of the urostyle, is measured from the tip of the snout to the tip of the vertebral column. In those specimens in which the urostyle is already formed, the measurement is to the middle of the caudal base. The DEPTH is measured at the origin of the pelvic fin. The HEAD is measured from the tip of the snout to the posterior edge of the membranous opercle, exclusive of projecting spines. The SNOUT is measured from the tip of the upper jaw to the anterior edge of the bony orbit. The ORBIT refers to the greatest horizontal diameter of the bony orbit, inside measurements. All measurements are given in millimeters.

Proportions, or indices are expressed as a percentage of the standard length, but the snout length and orbit diameter are also expressed as percentages of the head length.

Only fully formed spines and soft rays are included in the counts.

TAXONOMY AND DISTRIBUTION

Psenes cyanophrys Cuvier and Valenciennes, 1833

Figures 2 A-C; 3 D-F.

JUVENILE SYNONYMY.

Psenes cyanophrys Cuvier and Valenciennes. Günther, 1889:12-13 (compares a small series of *P. cyanophrys* with other species of *Psenes* described by Cuvier and Valenciennes, 25.5-76.0 mm total length). Norman, 1927:350 (30.0 mm specimen, 3°46'00"N, 16°49'00"W). Weber, 1913:152 (describes distribution of 10 specimens of *P. cyanophrys*, 16.0-85.0 mm from Celebes and Banda Seas). Longley and Hildebrand, 1941:75 (150 specimens up to 120 mm picked up from wastes of a bird rookery in Tortugas, Florida).

The genus *Psenes* has been referred to several families by different authors and the exact taxonomic position of the genus is not clear even now. In confusion of certain overlapping characters, various

authors have included the group in the families Carangidae, Stromateidae and Nomeidae.

The genus *Psenes* was first described by Cuvier and Valenciennes (1833) and included five species: *P. guamensis*, *P. javanicus*, *P. auratus*, *P. leucurus*, and *P. cyanophrys*. The last was described from a single specimen, 5 inches long, from New Ireland, off northeast New Guinea.

Lütken (1880) gave an account of young stages, not exceeding 87.0 mm, of *P. cyanophrys*. Together with *Psenes maculatus*, he recognized them as forms well distributed in the Atlantic Ocean.

Day (1888), in his work on the fishes of India, Ceylon and Burma, described two species of *Psenes* with the carangids: *P. indicus* and *P. javanicus*. Jordan and Evermann (1896), Weber (1913) and de Beaufort and Chapman (1951) have recognized the latter as a synonym of *P. cyanophrys*.

Günther (1889), in his studies of the pelagic fish collection made by the CHALLENGER, through an examination of a long series of specimens, found that the several species of *Psenes* described previously by Cuvier and Valenciennes (1833) were actually *Psenes cyanophrys* whose distribution is pelagic in the tropical Atlantic, Pacific, and Indian Oceans. He listed a new species, *P. arafurensis*, and along with other occurring nomeids he included them in the family Nomeidae.

Goode and Bean (1895) recorded two species of *Psenes*, but neither of them was *P. cyanophrys*. They were collected below 400 fathoms by the ALBATROSS at 32°—37°N, 73°—76°W, and placed in the family Nomeidae.

Jordan and Gilbert (1882) according to Baldwin (1954, unpublished) stated that the Nomeidae contains five genera and ten species. They separated it from the carangids because of the increased number of vertebrae, and grouped it, because of the teeth in the pharynx, with the family Stromateidae.

The family Nomeidae, according to Jordan and Evermann (1896), has 6 to 8 genera and about 15 species, mostly of the open seas, composed of small fishes rarely used as food. They added *P. regulus* Poey to their list of *Psenes*.

Fowler (1906) described a new species, *Psenes chapmani*, which he placed in the family Nomeidae, which were taken from northwest of the Cape Verde Islands, from northwest of the Lesser Antilles and from the Sargasso Sea. He compared his types with an East Indian

form, *Psenes guttatus*, and with *P. edwardsii* Eigenmann. In his work on marine fishes of West Africa, Fowler (1936) himself synonymized *P. chapmani* with *P. cyanophrys*.

Weber (1913), while examining the fish collection of the SIBOGA expedition, separated a small series of *P. cyanophrys* ranging in size from 16 mm to 85 mm taken from the surface waters of the Celebes and Banda seas.

Psenes pacificus was one of the new species of fish described by Meek and Hildebrand (1925) from Panama. They noted this fish to be rather close to *P. cyanophrys*, and grouped it with the stromateids.

In the marine fish collection of R. R. S. DISCOVERY, Norman (1930) recognized two species of *Psenes*: *P. cyanophrys* and *P. pellucidus*, which he listed in the family Stromateidae.

The largest specimens of *P. cyanophrys* were recorded by Longley and Hildebrand (1941) with the family Nomeidae in their catalogue of fishes of Tortugas. Specimens up to 120 mm were picked up from the wastes of a bird rookery, having been regurgitated together with *Monacanthus hispidus*, *Trachurops crumenophthalma* and *Caranx ruber*. The combination indicated a pelagic habitat, possibly occurring about the *Sargassum*, where young *Monacanthus hispidus* and *Caranx ruber* are common.

In the Indo-Australian archipelago, de Beaufort and Chapman (1951) recorded three nomeids including a new species, *P. whiteleggi*, in the family Stromateidae. They noted that the young of this fish are pelagic, often in shoals, and the adults probably live in deep waters. These workers also recognized the other four species of *Psenes* described by Cuvier and Valenciennes (1833) to be synonyms of *P. cyanophrys*.

In his checklist of Philippine fishes, Herre (1953) listed another species, *P. extraneus*, known from a single specimen bought in one of the local markets, probably used as food. He included the occurring species of *Psenes* under the family Nomeidae.

From the brief survey of the literature, it is apparent that the genus *Psenes* is badly in need of taxonomic revision. Until this has been done, the differentiation of the various species of this genus is not feasible.

The past records on the range of distribution of *Psenes cyanophrys* suggest a circumtropical occurrence, although stragglers, presumably, are reported as far north as Long Island (Hubbs, 1929)

and No Man's Land, off Martha's Vineyard (Miller, 1946).

The postlarval and juvenile specimens included in this work were found to be conspecific with the specimens of *Psenes cyanophrys* Cuvier and Valenciennes described by Jordan and Evermann (1896, pp. 950-51, and de Beaufort and Chapman (1951, pp. 88-89, fig. 18).

In *Psenes cyanophrys*, the preopercular margin with its mode of spination, and the general round appearance served to distinguish it from other carangoid and nomeid larvae with which it bears close resemblance in the postlarval stage. The fin ray counts and relatively small pelvic fins proved to be the most reliable distinguishing characters in the juveniles.

TABLE 2

MEASUREMENTS (IN MM) OF THIRTY POSTLARVAL AND JUVENILE SPECIMENS OF *Psenes cyanophrys* CUVIER AND VALENCIENNES.

Station	Standard Length	Head Length	Snout Length	Eye Diameter	Depth
Yucatan, 89	2.5	.6	.1	.3	1.1
Yucatan, 89	3.2	1.2	.5	.5	1.6
SL 40 B-0	4.7	2.1	.6	.8	2.3
SL 25 A-0	6.9	2.7	.9	.8	3.1
SL 14 C-0	9.4	3.8	1.0	1.4	4.8
NG 32-39	17.0	6.0	1.6	2.4	9.0
Yucatan, 89	17.5	7.0	1.8	2.2	9.3
SL 14 B-0	18.0	6.5	1.5	2.5	10.0
SL 20 A-0	18.5	6.5	1.5	2.8	10.0
Yucatan, 79	18.5	7.0	1.6	2.8	10.0
SL 18 B-0	18.5	6.6	1.5	2.8	11.0
Yucatan, 89	19.0	8.0	1.8	2.6	11.0
Yucatan, 89	20.0	8.0	1.7	2.8	11.0
NG 32-39	21.0	8.0	2.0	2.8	11.8
Yucatan, 89	21.5	8.0	2.0	2.8	12.0
Yucatan, 10	21.5	9.0	2.2	3.0	13.5
Yucatan, 10	22.0	8.0	2.0	3.0	12.0
Yucatan, 89	22.5	8.0	2.1	3.0	12.0
Yucatan, 89	24.0	9.0	2.1	3.0	14.0
Yucatan, 89	25.0	9.0	2.0	3.2	14.0
Yucatan, 89	26.0	9.5	2.3	3.0	15.0
Yucatan, 10	33.0	11.5	3.0	4.0	16.0
SL 19 B-0	33.5	12.0	3.0	4.0	15.0
Yucatan, 10	37.5	13.0	3.5	4.5	18.0
Yucatan, 84	38.0	12.5	3.0	4.0	19.0
Yucatan, 10	40.0	13.5	3.5	5.0	19.0
Yucatan, 10	40.0	14.0	3.5	5.0	20.0
Yucatan, 84	43.0	14.5	3.5	5.0	20.0
Yucatan, 84	44.5	15.5	4.0	5.0	22.0
Yucatan, 74	66.0	21.0	5.0	7.0	32.0

TABLE 3

SPINEY AND SOFT FIN RAY COUNTS OF THIRTY POSTLARVAL AND JUVENILE SPECIMENS OF *Psenes cyanophrys* CUVIER AND VALENCIENNES.

Station	Stand. Length	Dorsal Fin	Anal Fin	Pectoral Fin	Pelvic Fin
Yucatan, 89	2.5	-	-	-	-
Yucatan, 89	3.2	-	-	-	-
SL 40 B-0	4.7	-	-	15	2
SL 25 A-0	6.9	VII,27	III,26	17	I,3
SL 14 C-0	9.4	X-I,27	III,26	18	I,5
NG 32-39	17.0	X-I,27	III,28	19	I,5
Yucatan, 89	17.5	IX-I,26	III,27	19	I,5
SL 14 B-0	18.0	X-I,26	III,28	18	I,5
SL 20 A-0	18.5	X-I,26	III,28	20	I,5
Yucatan, 79	18.5	IX-I,28	III,27	18	I,5
SL 18 B-0	18.5	X-I,26	III,27	18	I,6
Yucatan, 89	19.0	X-I,27	III,27	19	I,5
Yucatan, 89	20.0	X-I,27	III,26	18	I,5
NG 32-39	21.0	X-I,27	III,27	18	I,5
Yucatan, 89	21.5	IX-I,26	III,27	18	I,5
Yucatan, 10	21.5	IX-I,27	III,26	18	I,5
Yucatan, 10	22.0	IX-I,27	III,27	19	I,5
Yucatan, 89	22.5	IX-I,26	III,27	18	I,5
Yucatan, 89	24.0	IX-I,26	III,27	19	I,5
Yucatan, 89	25.0	X-I,26	III,26	18	I,5
Yucatan, 89	26.0	IX-I,26	III,27	18	I,6
Yucatan, 10	33.0	X-I,26	III,27	18	I,5
SL 19 B-0	33.5	X-I,27	III,27	18	I,5
Yucatan, 10	37.5	IX-I,26	III,26	19	I,5
Yucatan, 84	38.0	X-I,27	III,27	18	I,5
Yucatan, 10	40.0	IX-I,26	III,27	18	I,5
Yucatan, 10	40.0	X-I,26	III,27	18	I,5
Yucatan, 89	43.0	X-I,27	III,26	18	I,5
Yucatan, 89	44.5	X-I,26	III,26	18	I,5
Yucatan, 74	66.0	X-I,26	III,26	18	I,5

TABLE 4

BODILY PROPORTIONS OF THIRTY POSTLARVAL AND JUVENILE SPECIMENS OF
Psenes cyanophrys CUVIER AND VALENCIENNES.

Station	Stand. Length	Depth Index	Head Index	Snout Index	Snout Head Index	Eye Index	Eye-Head Index
Yucatan, 89	2.5	44.0	24.0	4.0	16.6	12.0	50.0
Yucatan, 89	3.2	50.0	37.5	18.7	41.0	15.6	41.0
SL 40 B-0	4.7	48.9	44.7	12.7	28.5	17.0	38.0
SL 25 A-0	6.9	44.9	39.1	13.0	33.3	11.6	29.6
SL 14 C-0	9.4	51.0	40.4	10.6	26.6	14.9	36.8
NG 32-39	17.0	52.9	35.2	8.1	25.7	14.1	40.0
Yucatan, 89	17.5	53.1	40.0	10.2	23.0	12.5	31.4
SL 14 B-0	18.0	55.5	36.1	8.3	23.0	13.8	38.4
SL 20 A-0	18.5	54.0	35.1	8.1	23.0	15.1	43.1
Yucatan, 79	18.5	54.0	37.8	8.6	22.8	13.5	35.7
SL 18 B-0	18.5	53.5	35.0	8.2	22.2	15.0	43.0
Yucatan, 89	19.0	57.8	42.1	9.4	22.5	13.6	32.5
Yucatan, 89	20.0	55.0	40.0	8.5	21.2	14.0	35.0
NG 32-39	21.0	56.1	38.1	9.5	25.0	13.3	35.0
Yucatan, 89	21.5	55.8	37.2	9.3	25.0	13.0	35.0
Yucatan, 10	21.5	62.8	41.8	10.2	24.4	14.0	33.3
Yucatan, 10	22.0	54.5	36.3	9.0	25.0	13.6	37.5
Yucatan, 89	22.5	53.3	35.5	9.3	26.2	13.3	37.5
Yucatan, 89	24.0	58.3	37.5	8.7	23.3	12.5	33.3
Yucatan, 89	25.0	56.0	36.0	8.0	22.2	12.8	35.5
Yucatan, 89	26.0	57.7	36.5	8.8	24.2	11.5	31.5
Yucatan, 10	33.0	48.4	34.8	9.0	26.0	12.1	34.7
SL 19 B-0	33.5	46.2	35.8	9.0	25.0	12.0	33.3
Yucatan, 10	37.5	48.0	34.6	9.3	27.0	12.0	34.6
Yucatan, 84	38.0	50.0	32.8	8.0	24.0	10.5	32.0
Yucatan, 10	40.0	47.5	33.7	8.7	26.0	12.5	37.0
Yucatan, 10	40.0	50.0	35.0	8.7	25.0	12.5	35.0
Yucatan, 84	43.0	46.5	33.7	8.1	24.1	11.6	34.4
Yucatan, 84	44.5	49.4	34.8	9.0	25.8	11.2	32.2
Yucatan, 74	66.0	48.4	31.8	7.5	23.8	10.6	33.3

DEVELOPMENT

SPECIMENS STUDIED.

Twenty-one specimens (2.5-66.0 mm standard length) from five stations in the Caribbean Sea and the Straits of Florida (complete data given in Table 1).

Seven specimens (4.7-33.0 mm standard length) from seven SL stations (complete data given in Table 1).

Two specimens (17.0-21.0 mm standard length) from two NG stations (complete data given in Table 1).

From an array of carangoid and nomeid postlarvae those of *Psenes cyanophrys* showed a most conspicuous roundness at the head, a very fine mode of spination at the preopercular margin, and relatively small pelvic fins.

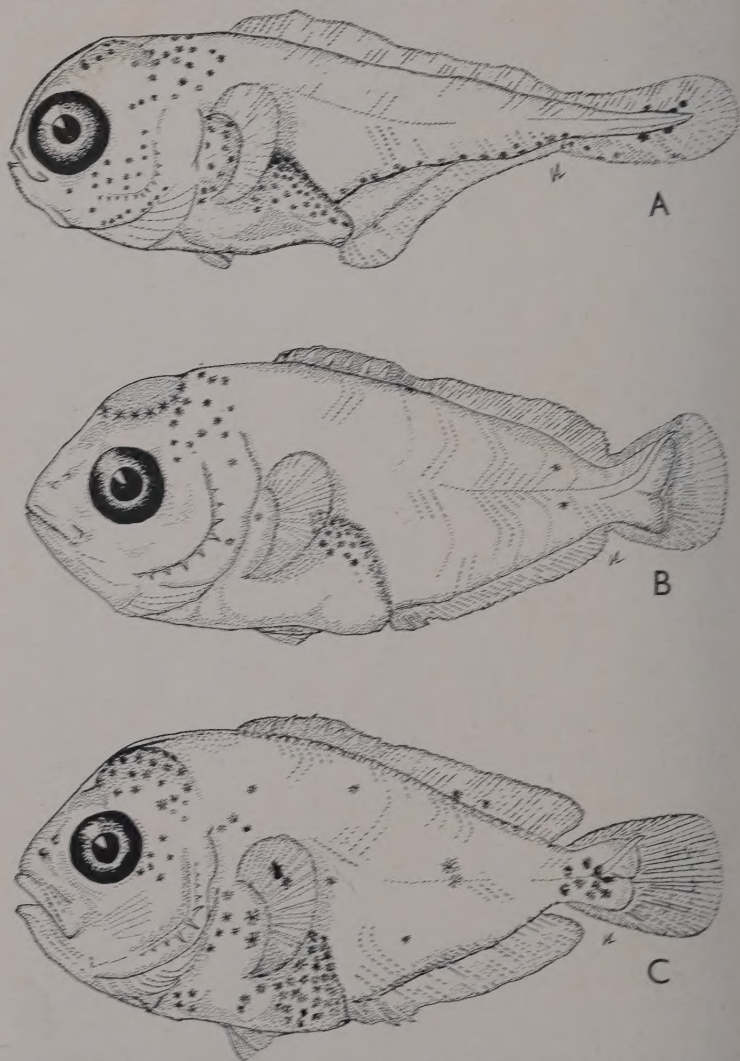


FIGURE 2A-C. *Psenes cyanophrys* Cuvier and Valenciennes: A-2.5 mm specimen; B-3.2 mm specimen; C-4.7 mm specimen.

Tables 2 and 3 show all the measurements and spiny and soft fin ray counts of all the specimens studied, and Table 4 gives the bodily proportions.

The smallest specimen, 2.5 mm (Figure 2A), has presumably just completed the absorption of yolk. The snout is extremely short and blunt, 4.0 per cent of the standard length; the jaws equal, and the eyes are very large, 50.0 per cent of the head. The pectoral fins are set on a fleshy base and are rounded, with evidence of developing fin rays. The dorsal and anal fins are confluent with the rounded caudals presenting a continuous contour outline. Between the bases of the pectoral fins, rudiments of the pelvic fins are present. The vertebral column is straight and rod-like. Chromatophores are quite evenly distributed on the head and nape, scattering through the cheeks and opercle. A few are also scattered at the base of the pectoral fins, on the sides of the body cavity and on the ventral side of the body to the tip of the vertebral column. The myotomes are indistinct.

At 3.2 mm (Figure 2B), several changes are evident. Over the short size interval of 0.7 mm, development has progressively taken place. The body deepens dorsoventrally, assuming a more compact appearance. The snout is conspicuously longer, 41 per cent of the head, with two pairs of nostrils visible. The fine serrations on the preopercular margin are now distinctly spinous. The pectorals show more fin rays in evidence. There are spines developing on the dorsal and anal fins which are now differentiating from the expanding caudal fin. All the unpaired fins have the fin ray elements developed. The pelvic fins have grown but the ventral sheath is not yet visible. The urostyle makes its appearance with evidence of the hypurals ventral to it. The myotomes at the posterior region of the body are more evident, forming a zigzag pattern. The chromatophores are retained except on the preopercle, ventral side and tail. Those on the head form a crown.

At 4.7 mm (Figure 2C), the fish assumes an adult-like appearance. The body tapers off posteriorly. The snout has decreased, 28 per cent of the head, approximating the juvenile proportions. The spines on the preopercular margin have grown but are distinctly weak. The second longest has made a downward bend giving the preopercular margin a characteristic pattern. The pectoral fins now have several fully formed fin rays with indications of more in formation. In the pelvic fin, a single spine is developing and fin ray elements are present. The dorsal and anal fins which have completely separated

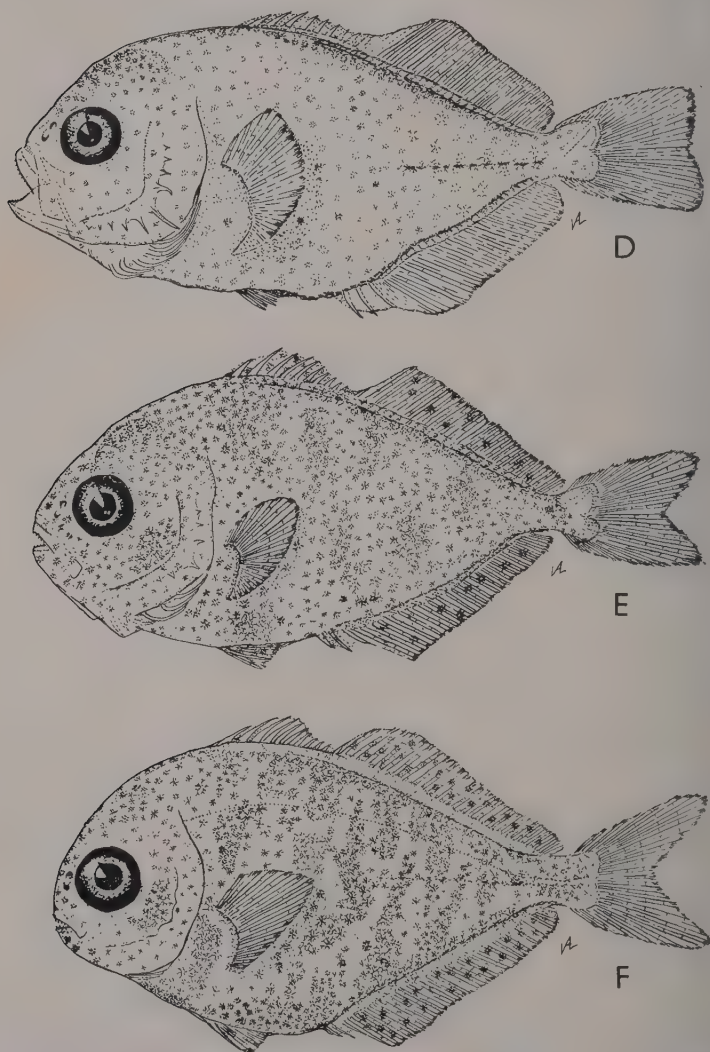


FIGURE 3D-F. *Psenes cyanophrys* Cuvier and Valenciennes: D-6.9 mm specimen; E-9.4 mm specimen; F-17.0 mm specimen.

from the caudals have developing spines, but none of the fin rays is completely formed. The caudal is well defined, rather truncate preparatory to forking. The chromatophores are concentrated on the head, abdominal wall and caudal base. A few are distributed on the sides. The anterior myotomes are now evident.

At 6.9 mm (Figure 3D), the larval characters become exaggerated, while the adult characters make their first appearance. The mouth is oblique with the jaws bearing fine teeth. The eyes are relatively smaller. The preopercular spines are now at their longest stage. The longest spine slightly exceeds the subopercle. The previously rounded pectorals, which have an increased number of fully formed rays, show a tendency to become pointed. The dorsal and anal fins have expanded. Seven spines and twenty-two fin rays are fully developed in the dorsal fin. The dorsal sheath is evident. The pelvics are almost fully formed except for a complete adult fin ray count. The ventral sheath is also visible. Three spines and twenty-six rays are distinct in the anal fin. The caudal fin with fully developed middle rays has a shallow cleft giving it a slightly emarginate posterior margin. Adult pigmentation is becoming apparent. Chromatophores are evenly distributed throughout the body, slightly more close-set on the head and along the base of the dorsal and anal fins. There are no indications of the lateral line, but large chromatophores form a line on the mid posterior side of the body which gives the illusion of a lateral line.

Over a size range of 2.5 mm (6.9-9.4 mm specimens), the approximate adult proportions have been attained. The fish at 9.4 mm (Figure 3E) apparently starts a gradual change to juvenile form. The snout is much reduced. The preopercular spines have gradually shortened and are now half their length compared to those of the preceding fish. The pectorals are now assuming a more definite shape and ray counts are those of the adult. The dorsal and anal fins have the adult counts, 11 spines and 26 rays in the former, and 3 spines with the last spine attached to the first of the 26 rays in the latter. The pelvic fins are fully developed and distinctly smaller than the pectorals. The dorsal and pelvic sheaths are well developed. The pigmentation pattern of the adult is more pronounced. Chromatophores are distributed throughout the body concentrating in certain areas to form patches. The now completely developed caudal fin has a deeper cleft. The lateral line, however, is not yet discernible.

Although there is a long size gap to the next available specimen,

17 mm (Figure 3F), most of the larval characters are still evident. Through the 7.6 mm (9.4-17.0 mm specimens) size gap nearly all of the adult characters have taken over. The head has lost its oversized larval appearance, but the depth has increased to 51 per cent. The mouth is more oblique; the jaws, almost equal, bear a single row of fine teeth. The snout is shorter and remains thus in the larger specimens. The preopercular spines have almost completely receded, leaving only a crenulate margin. All the fins are fully developed except for the elongation of the pectorals producing a slightly falcate form in the adult. The skin has a rather rough texture, probably due to the incipient cycloid scales which in the larger sizes are completely laid down. Adult pigmentation predominates. The chromatophore patches are much denser, forming interrupted bands. The lateral line has made its first appearance as a faint, slightly convex line above the median line. The young fish is essentially similar to the adult and may now be termed a juvenile.

Discussion. It has been frequently generalized in developmental studies that animals or plants of the same species are more highly developed at a smaller size in tropical than in temperate areas. Larval fish development would undoubtedly conform with this generalization. However, no comparison can be made of *Psenes cyanophrys*, as this is a tropical and warm temperate species, and according to Longley and Hildebrand (1941) its northern limit is Florida. Nevertheless, even among closely related groups residing in the same locality, development proceeds at different rates. Voss (1954) found this to be true among her larval gempylids taken from the Florida Current and vicinity.

From the overall study of the larval and juvenile stages of *P. cyanophrys*, development in the postlarval stage is noticeably rapid. In the 2.5 mm larva, all the fins are present, although rudimentary and not well differentiated. The pectorals are the most prominent of these fins. According to Regan (1916), the pectoral fins which are principally concerned with balancing are present in the youngest fish larvae.

In order to show the changes that take place from the early postlarval to the late juvenile forms, a series of graphs were constructed using the bodily proportions of the thirty specimens studied. Figures 4 and 5 show the relationship of the various measurements to standard lengths, and in some cases to head length, of the specimens.

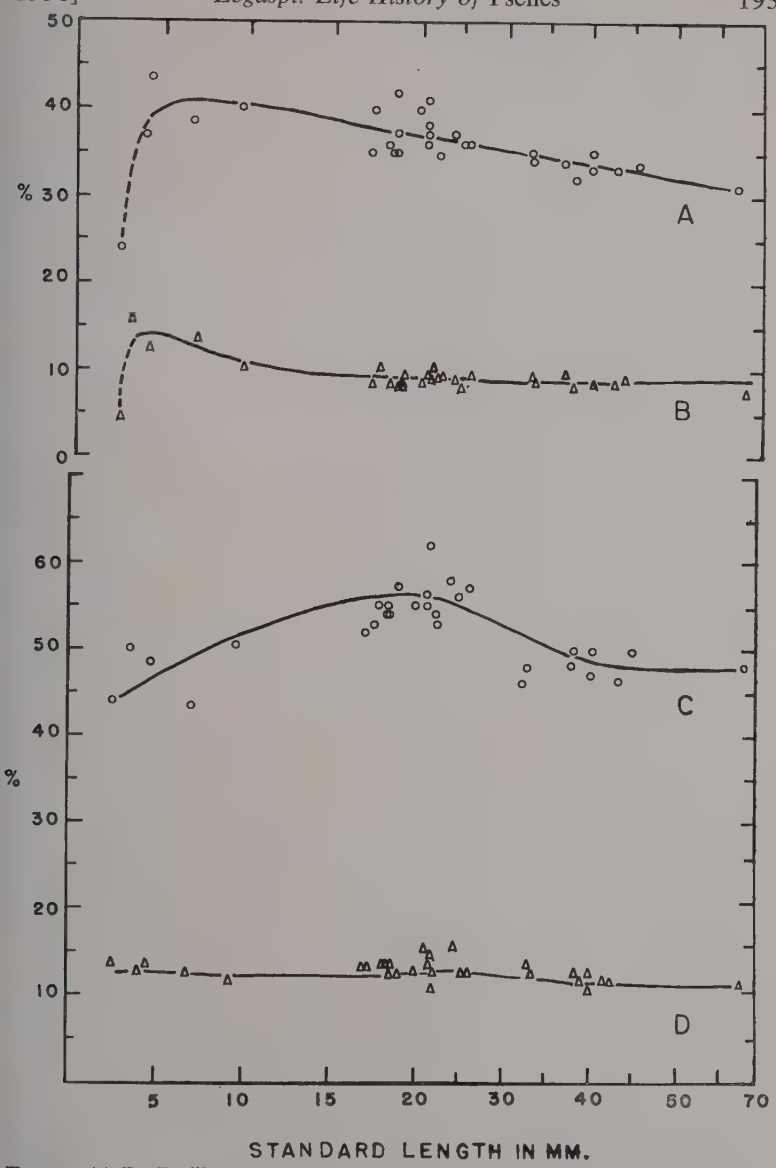


FIGURE 4A-D. Bodily proportions of thirty specimens of *Psenes cyanophrys* Cuvier and Valenciennes: A-Head to standard length; B-Snout to standard length; C-Depth to standard length; D-Eyes to standard length.

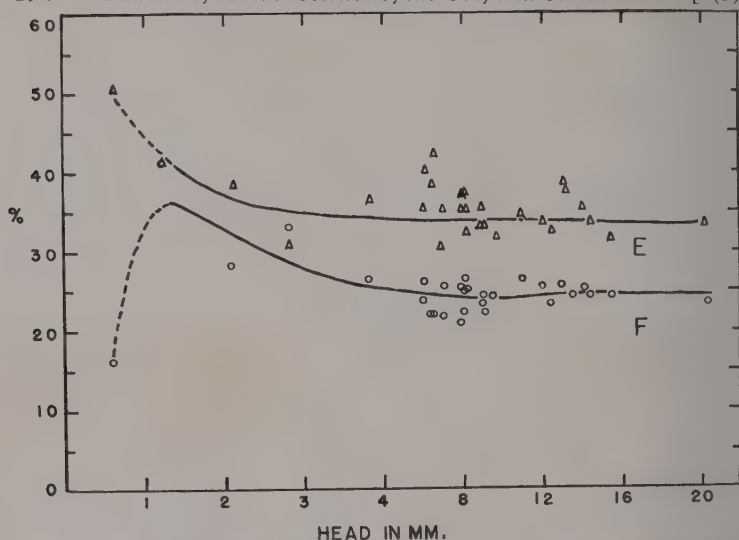


FIGURE 5E-F. Bodily proportions of *Psenes cyanophrys* Cuvier and Valenciennes: E-Eye to head length; F-Snout to head length.

In all the larval and juvenile specimens, the greatest depth is at the origin of the pelvic fins, and reaches its peak in the juvenile stage at about 21 mm (Figure 4C). The relationship of the eye to length does not show a postlarval or juvenile peak but presents a practically constant ratio throughout the entire size range (Figure 4D).

The exaggerated characters which distinguish the postlarval stage are most pronounced over a range of about 5 mm, from the 4 mm to the 13 mm size stages (Figures 4A; 4B; 5E; 5F). At 17 mm, the young fish is distinctly a juvenile, and growth then proceeds until adulthood is attained. There is no true metamorphosis and development is direct.

BIOLOGY

Food. The author has been unable to find any mention in the literature concerning the food or feeding habits of this fish. All of the specimens reported on in this paper were later dissected. Most of the stomachs were found to be much distended, and upon examination of their contents, copepods appeared to constitute the basic diet, as in the case in many young fish.

Table 5 lists the stomach contents of the postlarvae and juveniles examined.

TABLE 5
Stomach Contents of 30 Postlarval and Juvenile Specimens of
Psenes cyanophrys.

Standard length in mm	Contents of Stomach
2.5	digested copepods
3.2	digested copepods
4.7	3 copepods
6.9	empty
9.4	5 copepods, 2 fish eggs
17.0	digested copepods
17.5	4 copepods, 1 chaetognath
18.0	8 copepods, 2 fish eggs
18.5	digested copepods
18.5	6 copepods
18.5	empty
19.0	empty
20.0	5 copepods, 4 chaetognaths
21.0	digested copepods
21.5	10 copepods, 2 chaetognaths
21.5	4 copepods
22.0	digested copepods, 1 chaetognath
24.0	3 copepods, 3 chaetognaths
	1 fish egg
25.0	digested copepod, 1 fish egg
26.0	7 copepods, 3 chaetognaths
33.0	11 copepods, 2 chaetognaths
	1 fish egg, 1 fish larva
33.5	digested copepods
37.5	9 copepods, 1 amphipod
38.0	digested copepods
40.0	empty
40.0	6 copepods
43.0	4 copepods, 1 chaetognath
44.0	5 copepods
66.0	digested copepods

From the above table, it is seen that in the very small fish, the food is apparently mainly copepods, but with increase in size, there appears to be a mixed diet of fish eggs, fish larvae, amphipods and chaetognaths as indicated by the stomach contents. In most of the specimens only the exoskeletal remains of copepods were discernible, with the softer parts already in an advance state of digestion. The identifiable ones were mostly calanoids but they were in such poor condition that identification to species was not attempted. Eleven copepods was the largest number to be found in any one larva. The only fish larva, 8.0 mm long, was taken in the stomach of a 33.0 mm juvenile. In all cases, from five to ten specimens of an internal parasite of some kind,

measuring from 0.5 mm to 2.0 mm in length, were found in the folds of the stomachs.

Spawning. Very few adults of *Psenes cyanophrys* have been taken in the past and no gonadal studies have been carried out to determine the time of spawning. Gunther, however, had a series of specimens which he referred to as *P. cyanophrys* ranging in size from 24.0 mm to 74.0 mm, which presumably are late juveniles. They were taken from different localities: between Tencrife and St. Thomas; Gulf Weed, south of Bermuda; south of New Guinea; the Philippines; north of Papua; and Japan, during the months of February, March, April, May and August. Day's *P. javanicus* (= *cyanophrys*) was caught in October.

This report includes the study of thirty postlarvae and juveniles of *P. cyanophrys* ranging in size from 2.5 mm to 66.0 mm standard length. They were collected from Caribbean waters between Grand Cayman and Cape Camaron (Honduras), the Straits of Florida, and the waters between the southeastern coast of Florida and the Bahamas, mainly in the Florida Current and vicinity (Figure 1). The specimens were taken in March, April, May, July, August and October. Although the size ranges in the three localities are not uniform, being 4.7 mm-33.5 mm in length from the Florida coast and the Bahamas, 21.5-40.0 mm in length from the Straits of Florida, and 2.5-66.0 mm in length from the Caribbean area, the wide distribution of the larvae and juveniles indicates that this fish spawns over an area of considerable extent. The lack of specimens of smaller size in the Straits of Florida may be due to poor sampling.

Table 6 lists the length range and the corresponding time of the year the specimens were taken.

TABLE 6
DISTRIBUTION OF LARVAE AND JUVENILES BY MONTHS OF THE YEAR OF
Psenes cyanophrys.

Month	Length of Larvae
January	0
February	0
March	9.4-18.0
April	2.5-66.0
May	6.9
June	0
July	18.5
August	17.0-33.5
September	0
October	4.7-18.5
November	0
December	0

In the above table, it is shown that the postlarvae occurred in the areas mentioned from March to October except in June and September. No prolarvae were taken; the smallest postlarva was 2.5 mm, probably in its earliest postlarval existence.

The occurrence of juveniles in almost all the months that the species was taken apparently indicates that *P. cyanophrys* spawns in the Caribbean and Florida waters throughout the greater part of the year, mainly from late winter through fall.

Vertical Distribution of the Young. The 30 postlarvae and juveniles included in this report were all taken from the surface waters (0 depth), and no vertical distribution nor movement can be shown. The juveniles, mostly, of *Psenes cyanophrys* together with those of *Caranx ruber* and *Caranx bartholomei* were frequently picked out from clumps of Sargasso weed by dip netting along the Florida Current. These fishes, along with certain other free-swimming animals, constitute part of the characteristic fauna of the floating Sargasso weed.

This occurrence denotes a strictly pelagic existence, at least in the younger stage, as far as the population of *P. cyanophrys* in the Florida and Caribbean waters is concerned. However, more extensive collections may give more data on the vertical distribution of this fish.

Hydrographic Conditions. The postlarvae and juveniles were taken in waters with a surface temperature ranging from 26.64°-28.8°C and a salinity range of 34.83-36.0‰. The narrow ranges of these figures can be applied only to the young since we have no data concerning temperature and salinity tolerances for the adults. The early stages generally are the most critical period in the life history of marine animals as the sensitivity to environmental fluctuation is then generally greater than at any other period in their life span.

SUMMARY

1. The family position of the genus and its occurrence in the tropics is discussed. Previous records of juveniles and adults of *Psenes cyanophrys* Cuvier and Valenciennes are given.

2. The materials and methods of collection and study of the postlarvae and juveniles of *P. cyanophrys* from the Caribbean Sea, Straits of Florida and Florida Current is summarized.

3. The taxonomic significance of larval characters is discussed. In *P. cyanophrys*, the preopercular margin with its mode of spination, the general round appearance and the fin ray counts are the taxonomically important larval and juvenile characters.

4. A series of 30 postlarvae and juveniles of *P. cyanophrys* Cuvier and Valenciennes, ranging in size from 2.5 to 66.0 mm standard length, are described and illustrated. These are the smallest specimens of this species yet recorded.

5. The bodily proportions are presented in indices and graphs illustrating the gross morphological changes occurring through development and growth. The larval characters are most pronounced over a range of about 9 mm, from the 4 mm to 13 mm size stages. At 17.0 mm the young nomeid is distinctly juvenile, and growth then proceeds until adulthood is reached. There is no true metamorphosis and development is direct.

6. The general biology of *P. cyanophrys* based on available data on food, spawning and hydrographic conditions is discussed. This species is apparently a surface dwelling fish, living primarily upon planktonic forms such as copepods, amphipods, fish eggs and larvae and chaetognaths, in the younger stages. Spawning, as determined by the presence of young in all the months that the specimens of *P. cyanophrys* were taken, occurs from late winter to fall in Florida and Caribbean waters. The hydrographic data indicate a narrow range of tolerance for temperature and salinity in the young nomeids.

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OXIDATION-REDUCTION POTENTIALS OF THE WATER AND SEDIMENTS OF BARATARIA BAY, LOUISIANA

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ABSTRACT

The oxidation-reduction potential (O/R) of Barataria Bay surface water varied from +30 to +300 millivolts. The low readings were found in Hackberry Bay near oil operations and in Lake Grande Ecaille near the Freeport Sulfur Company plant. In many cases the O/R of the water 3-4 inches above the bottom was higher than at the surface. This was presumed to be due to the extensive activity of algae at this level. Most of the muds tested in Barataria Bay gave readings below 0 millivolts but there were a few positive readings. The lowest readings on mud (-200 to -300 millivolts) were in the same areas showing low surface readings.

INTRODUCTION

Oxidation-reduction potentials (O/R) are indicative of the biochemical environment and provide a good criterion of the chemical and biological conditions prevailing in waters and sediments. At high positive O/R values elements such as iron, sulfur, and nitrogen exist chiefly in the oxidized form as ferric sulfate and nitrate; at negative O/R values the salts would be mainly ferrous sulfate, nitrates and sulfides (Pearsall and Mortimer, 1939). Aerobic organisms predominate under positive O/R conditions, anaerobic or facultative organisms find conditions favorable for their activity under conditions of negative O/R potentials.

Oxidation-reduction potential measurements were made of the water and sediments of the Barataria Bay area in order to obtain information concerning the chemical and biological "climate" in this region. Barataria Bay is several hundred square miles in extent, and is only 3 to 6 feet deep over most of its area. The salinity varies from about 30 parts per thousand (ppt) in the south to 10 ppt in the northern portion. Fresh water enters the bay through several channels carrying drainage from the area between the Mississippi River and Bayou Lafourche. Tidal currents cause wide fluctuations in salinity in parts of the bay.

The microbial activity of water or bottom sediments is suggested by the O/R potential. Where ample food materials are available

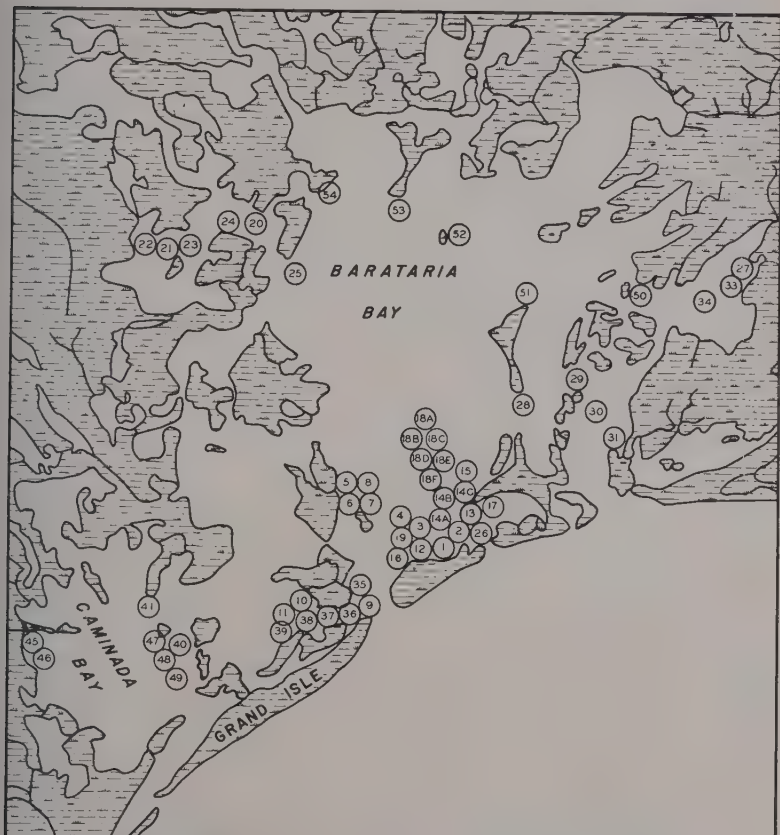


FIGURE 1. Stations at which readings were taken in Barataria Bay.

to bacteria they rapidly reduce the O/R potential to a low level unless abundant oxygen is supplied by physical agitation and aeration, or by photosynthetic activity of green plants. A high positive O/R potential therefore indicates one or more of the following conditions: the microbial food supply is scanty, the photosynthetic activity of algae is high or solution of atmospheric oxygen is increased due to agitation of wind and waves.

Several workers have reported observations on the O/R values

of waters in the sea and in lakes. ZoBell (1946a) stated that the potential has an effect on the speed and magnitude of chemical reactions and that the O/R may influence bottom deposits in many ways. Lowering (1927) reported that bacteria, by creating reduced conditions, may promote the precipitation of copper, vanadium, and other minerals.

Cooper (1937) found the O/R potential of sea water to be near +430 millivolts. The O/R potential increased as the pH decreased. Hutchinson, Deevey and Wollack (1939) reported an O/R potential +460 to +500 millivolts for fresh water. Zobell (1946b) determined the O/R potential of 1,000 samples of bottom deposits taken off the coast of Southern California, and found the values to range from +350 to -500 millivolts.

METHODS

The O/R potentials were determined with a Beckman model N potentiometer using calomel and platinum electrodes with ten foot leads. The electrodes and leads were attached to a seven foot pole with friction tape, and the electrodes were protected with a galvanized wire mesh. Using this equipment it was possible to get O/R values of the muds and waters without taking samples; therefore the possibility of a change in potential due to removal of the mud or water from its location was avoided. The determinations reported here were made during the months of June, July, and August, 1955.

RESULTS

Oxidation-reduction potentials distributed over a large portion of Barataria Bay are given in Table 1. The location of the readings are shown in Figure 1. The surface readings were mostly within usual ranges that have been reported for sea water (Cooper, 1937, and Zobell, 1946b). Some areas had readings much below the readings reported for surface sea water. A reading of +60 millivolts one mile northwest of Sugar Bend (15) over an oyster bed, and a reading of +96 millivolts two miles southeast of Independence Island (16) are somewhat below the usual readings reported for sea water. There is no explanation for these low readings except that the water was very rough the day these measurements were taken and possibly the highly reduced bottom mud was being mixed with the water.

Hackberry Bay is another area that gave very low surface readings (determinations 20, 21, 22, 23, and 24). There are extensive oil operations in Hackberry Bay, bacterial counts were high in this area, and there was significant pollution with coliforms.

Very low surface readings were also found in Cat Bay, Bay Ronquille and Lake Grande Ecaille (determinations 27, 28, 30, 31, 32, 33, and 34). All of these areas are in the vicinity of the Freeport Sulfur Company operations.

It will be noted in Table 1 that in most cases the O/R at the bottom (3-4 inches above the bottom) was higher than at the surface. Since the bottom sediments were highly reduced it was not expected that the O/R would be higher near the bottom than near the surface. The explanation appears to be that the algal activity was sufficient at this level to keep the water saturated with oxygen. O/R potential measurements of bottom sediments varied from +126 to -300 millivolts. Those areas with highly reduced mud, -200 to -300 millivolts, were the same areas which showed low surface readings: Hackberry Bay with its oil operations and Lake Grande Ecaille with the sulfur plant. All the mud tested in Hackberry Bay was very soft and had a strong odor of hydrogen sulfide. Over most of the Bay the sediments are soft and slushy and in some areas the bottom "ooze" is several feet thick.

DISCUSSION

The O/R potentials of the waters of Barataria Bay were found to be within normal ranges that have been reported for sea water by Cooper (1927). Since the O/R potential is primarily a function of oxygen content, it appears that the dissolved oxygen in Hackberry Bay and in the vicinity of the sulfur plant is somewhat less than in other parts of Barataria Bay.

ZoBell (1946b) reported the O/R of marine sediments off the coast of Southern California to be from -200 to -500 millivolts. Bacteria are able to create such reducing conditions (Zobell, 1939 and Hewitt, 1936), and no doubt are responsible for the reduced conditions of Barataria Bay sediments.

It was unexpected that water only 3 to 4 inches from a highly reduced bottom would be more oxidized than surface water which is in contact with the atmosphere. One explanation for this phenomenon is that algae are abundant at this level and are keeping the water supplied with oxygen. Harvey (1928) stated that during the

TABLE 1. Oxidation reduction potentials of Barataria Bay*

Map number and location	Type of Bottom	Depth	Surface (6" to 1')	Redox potentials in millivolts		
				2'	5'	Bottom
1 Sugar Bend, over oyster beds.	Shell	5-1/2'	+252	+264	+306	+246
2 Sugar Bend, 300 yards east of above location.	Shell	5'	+252			+288
3 One-half mile east of Independence isle, over oyster beds.	Shell	6'	+252			+306
4 Two miles north of Independence isle.	Hard	7'	+246			+324
5 One-half mile west of oil well near Quatre Bayou.	Shell	5'	+234			+270
6 Three quarters of a mile west of oil well near Quatre Bayou over oyster beds.	Shell & Mud	5-1/2'	+174			+252
7 At state oyster sample cages near Quatre Bayou.	Shell	5-1/2'	+186			+240
8 200 yards west of above above location.	Mud		+210			+258
9 400 yards off Fifi island near mouth of Bayou Rigaud.	Hard Sandy	3-1/2'	+120			+138
10 50 yards off shore Mendicant Island	Shell	5-1/2'	+216	+228		+228
11 One mile west of above location.	Mud	4'	+210	+228		+252
12 Sugar Bend, later date than above readings.	Shell	5'	+186			+258
13 At old pier at Grand Bank.	Fairly hard mud with a few shells.	4'	+228			+12
14 The following readings (A, B and C) were taken over oyster beds east of						-6

* The following readings (A, B and C) were taken over oyster beds east of

TABLE 1. Continued.

Map number and location	Type of Bottom	Depth	Redox potentials in millivolts				
			Surface (6" to 1')	2'	5'	Bottom	Mud
Independence Island							
A-	Mud	5'	+222				-30
B-	Mud	5-1/2'	+222	+258			-12
C-	Shell	6'	+216	+222		+288	
15 One mile north west of previous reading at Sugar Bend, over oyster bed. Cloudy day, water rough.							
16	Shell	5'	+ 60	+ 72	+ 72		
16 Two miles south east of Independence Island. Outside of an oyster bed. Water rough.							
17	Mud	7-1/2-8'	+ 96	+120	+114		
17 Grand Bank - 100 yards from previous reading at this location.							
18	Mud	4'	+288	+330		+270	+ 6
18 The following readings were taken over oyster beds north-west of Grand Bank.							
A-	Shell	5-1/2'	+288	+324		+354	+30
B-	Mud	5'	+282	+339			
C-	Shell	6'	+288	+324	+348		
D-	Shell	6'	+258	+342	+360		
E-	Shell	6'	+318	+360		+384	
F-	Shell	6'	+330	+360		+378	
19 Three miles south Independence Island.							
20	Shell	6'	+300	+330		+360	-204
20 Entrance to Hackberry Bay.							
21	Soft Mud	3'	+ 84				
21 One mile east of barge Hackberry Bay.							
22	Soft Mud	4'	+ 60				-192
22 One-half mile east of barge, over an old oyster bed							
23	Soft Mud		+ 30				-234
23 Hackberry Bay. with a few shells							
		4-1/2-5'	+ 48				-192

* All O/R determinations were made during June, July and August 1955.

*All O/R determinations were made during June, July and August 1955.

TABLE 1. Continued.

Map number and location	Type of Bottom	Depth	Redox potentials in millivolts			
			Surface (6" to 1')	2'	5'	Bottom
24 At old shack near Hackberry Bay.	Mud	4'	+ 60			-222
25 Two miles out in open Barataria Bay from Hackberry Bay.	Mud Hard	6' 3'	+140 +126			-150 +126
26 Grand Bank	Mud	4'	+ 30			-300
27 Freeport Sulfur Co. Just off shore.	Mud	4'	+ 60			-150
28 Cat Bay	Mud	3'	+108			-120
29 Entrance Bay Ronquille	Mud	3'	+ 36			-210
30 Bay Ronquille	Mud	3'	+ 48			-192
31 Nook off Bay Ronquille	Mud	3'	+ 48			-252
32 Neck between Bay Ronquille and Lake Grand Ecaille	Mud	3'	+ 48			-252
33 Grand Ecaille near Sulfur Co.	Mud	4'	+ 30			-192
34 Center Lake Grand Ecaille	Mud	4'	+ 36			-204
35 Pipe line crossing at entrance to Bayou Fifi	Mud	3'	+102		+102	-54
36 One-half mile west of the above location.	Mud	5'	+258		+270	+ 24
37 One mile west of the above location.	Mud	3-1/2'	+186	+216		+ 60
38 Two miles west of pipe line crossing, Bayou Fifi.	Mud	4'	+186			0
39 Four miles west of pipe line crossing, Bayou Fifi.	Mud	3'	+ 96			-60
40 Entrance Caminada Bay	Mud	4'	+180		+102	-72
41 Two miles west of Andre' Isle light.	Mud	5'	+ 78	+144		
42 One mile inside S.W. La.						

TABLE 1. Continued.

Map number and location	Type of Bottom	Depth	Redox potentials in millivolts			
			Surface (6" to 1')	2'	5'	Bottom
Canal.	Mud	3-1/2'	+120	+136		-12
43 One-half mile inside S.W. La. Canal.	Mud	3'	+78			-24
44 Just inside S.W. La. Canal.	Mud	3-1/2'	+90			-96
45 Bay Lizette	Mud	4'	+126			-120
46 One mile south of S.W. La. Canal.	Mud		+102	+126		-120
47 Southeast tip of Andre' Isle	Mud	4'	+120	+136		-114
48 One mile toward Caminada bridge from Andre' Isle light.	Mud	4'	+120			-66
49 Two miles toward Caminada bridge from Andre' Isle light	Mud		+204			-18
50 West entrance Lake Grand Ecaille	Mud	4'	+48			-192
51 Grand Island Point	Mud	4'	+78			-100
52 Saturday Island	Mud	2'	+56			-96
53 One mile south of St. Mary's Point.	Mud	5'	+84			-168
54 Manila Village	Mud	4'	+36		+60 +96	-210

* All O/R determinations were made during June, July and August 1955.

summer months the water of shallow estuaries is often supersaturated with oxygen due to the presence of algae.

The highly reduced anaerobic conditions found in the bottom sediments of Barataria Bay leave no doubt as to the fate of oysters which might sink into the soft mud. The oxygen supply in the water appears to be adequate for fish life even to a point just slightly above the bottom, and oysters should do well as long as they are prevented from settling into the mud.

ACKNOWLEDGMENT

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CORRELATIONS OF VARIOUS AMBIENT PHENOMENA WITH RED TIDE OUTBREAKS ON THE FLORIDA WEST COAST¹

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ABSTRACT

Investigations have been made to determine whether any simple, linear correlations exist between Red Tide outbreaks and various ambient phenomena. Outbreaks are compared with rainfall, tropical disturbances, and river runoff. A pattern of cyclic recurrence of outbreaks is presented. An attempt is made to show the path of individual outbreaks.

INTRODUCTION

Investigations into the phenomena commonly called Red Tide have led some observers to believe that there may exist a simple, linear correlation between the series of reported Red Tide outbreaks, and an equivalent series of some single physical factor. Gunter, *et al.* (1947) and Slobodkin (1953) noted the possibility of such a correlation. Although examination of a single outbreak may suggest such relationships, examination of additional outbreaks often fails to support them. An exhaustive study of all available data which might be simply connected with Red Tide outbreaks, and of all reported outbreaks, was undertaken, to determine the existence of such relationships.

For the purposes of this paper, Red Tide was defined to mean either an incidence of dying or dead fish accompanied by discolored water, except in cases where an obvious cause of fish mortality, such as widespread abnormally low sea-water temperatures, was determined. "Aftermath phenomena" of a Red Tide was defined to mean either an incidence of dead fish in normal-appearing water, or decomposed dead fish, which were not otherwise explained.

The first section is concerned with the long-term, large-scale patterns of Red Tide occurrence; an attempt has been made to estimate relative intensity of outbreak, in units of one calendar year, from the literature. Estimates of intensity are dependent upon the interpretations of the descriptions of various writers. For this reason, they cannot be assigned absolute, quantitative values. The values given here, therefore, are not necessarily those which others, evaluating the same literature, might assume.

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The later sections are concerned with various ambient phenomena and their possible simple relationships to Red Tide outbreaks. The results of an attempt to correlate severe tropical disturbances and Red Tide years are shown graphically. Attempts were made to establish linear correlations between precipitation data for all of Florida or for the Peace River Drainage Basin and the years of outbreaks. Peace and Apalachicola River runoffs were similarly analyzed. Also, attempts were made to correlate river runoff and precipitation with Red Tide intensity as defined in the first section.

The last section contains some remarks on possible patterns of movement of Red Tide phenomena, using outbreak reports for the period February, 1954 through February, 1955, as illustrative material.

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TABLE 1
YEARS OF RED TIDE OUTBREAK WITH ESTIMATED
INTENSITY FACTORS

Year	Intensity of Outbreak	Intensity Factor	Number of years since Last Recorded Outbreak
1844	Heavy	5	unknown
1854	Moderate	3	10
1856	Light	1	2
1865	Moderate	3	9
1878	Heavy	5	13
1879	Light	1	1
1880	Moderate-heavy	4	1
1882	Light-Moderate	2	2
1883	Light	1	1
1885	Light	1	2
1886	Light	1	1
1916	Heavy	5	30
1924	Moderate	3	8
1925	Light-moderate	2	1
1931	Light	1	6
1932	Moderate	3	1
1936	Light-moderate	2	4
1946	Heavy	5	10
1947	Heavy	5	1
1949	Light	1	2
1951	Light	1	2
1952	Moderate-heavy	4	1
1953	Moderate-heavy	4	1
1954	Moderate-heavy	4	1

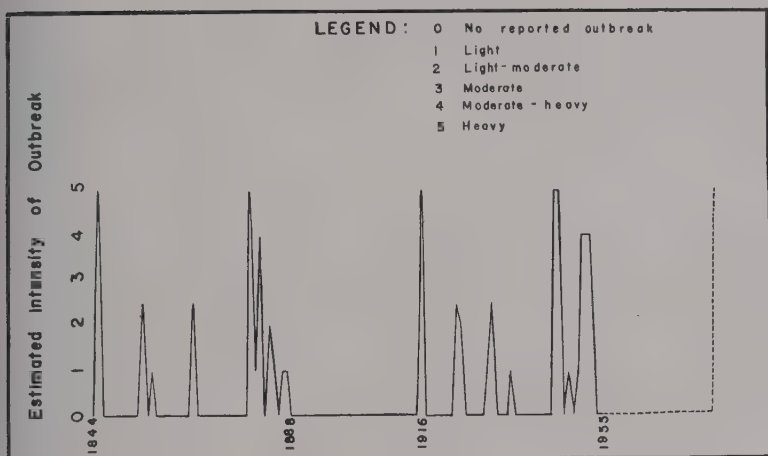


FIGURE 1. Estimated intensity of Red Tide outbreak 1844-1955.

LONG-TERM, GENERAL PATTERNS OF RED TIDE OUTBREAKS

All of the data given in Table 1, with the exceptions noted below, have appeared in a mimeographed report of The Marine Laboratory of the University of Miami to the Florida State Board of Conservation (Feinstein, *et al.*, 1955). The data of 1886 (Heilprin, 1887), 1887 (Harper, 1927), and 1925 (*ibid.*) were brought to the attention of the author by Mr. Robert B. Campbell of Fort Myers, Florida. The data of 1931 and 1936 were received by a member of the Laboratory staff in a personal communication.

Early reports of Red Tide phenomena (*i.e.* before 1946) were based upon verbal or letter reports from non-scientific observers and newspaper reports. The bulk of reports in the recent past also came from lay observers. Since the early reports were in less detail than the more recent reports, it was necessary to estimate the intensity of outbreak subjectively. Accordingly, an arbitrary scale of 0-5 was established. 0 represents no outbreak occurrence during the year in question, while 5 represents a maximum intensity of outbreak (Table 1). The variation in the intensity values assigned to each year suggests a long-term, general pattern of Red Tide occurrences from 1844 through 1955 (Figure 1).

The first recorded Red Tide outbreak (1844) was an outbreak of maximum intensity. From 1844 until 1887, there were intermittent

outbreaks of varying intensity. The outbreak of 1878 was the only other outbreak of maximum intensity during this period, while the 1880 outbreak reached an apparent intensity of 4. No Red Tide was reported from 1887 until 1916, when there was another outbreak of maximum intensity. From 1916 until 1955, there were intermittent outbreaks of varying intensity. The outbreak of 1946-1947 was the only other outbreak of maximum intensity during this period, while the 1952-1954 outbreaks reached intensity 4. It is interesting to note that the outbreaks of maximum intensity were preceded by at least ten years with no recorded outbreak.

The period from 1844 through 1954 can be divided into three sub-periods: 1844-1886, 1887-1915, 1916-1954. The first and last of these sub-periods were ones with intermittent Red Tide outbreaks, while no Red Tide was recorded during the second sub-period. Should this be a cyclic phenomenon, and should we assume a simple ratio relationship as, for example:

$$\frac{\text{no. years in 1st period}}{\text{no. years in 2nd period}} = \frac{\text{no. years in 3rd period}}{\text{no. years in 4th period}} \quad (1)$$

$$\text{i.e.,} \quad \frac{43}{29} = \frac{39}{x} \quad (1a)$$

then approximately 27 years after 1954, or in 1982, we might expect a Red Tide outbreak of maximum intensity. Should we assume that the third sub-period will be equal in length to the first one, i.e. 43 years, then the third sub-period will extend through 1958. Substituting in (1), the fourth sub-period will now equal 29 years, and will extend from 1959 through 1987. The next year with an outbreak of maximum intensity then will be 1988.

The data used in evolving the above patterns cover a period of 112 years. The Red Tide is certainly a recurring phenomenon, but there is no valid reason to assume that it is cyclic with constant periods. Yet Figure 1 is very suggestive.

THE RELATIONSHIP BETWEEN RED TIDE OUTBREAKS AND TROPICAL DISTURBANCES

Table 2 lists tropical disturbances which affected the west coast of Florida from Apalachicola south to the Florida Keys, as reported by the United States Weather Bureau (hereinafter referred to as the USWB) and Tannehill (1944). The data show (Figure 2) that there is no simple connection between Red Tide outbreaks and tropical

TABLE 2. HURRICANE DATA

H	Hurricane		* Material taken from Tannehill
T	Other tropical disturbance		** Material taken from USWB reports
O	No tropical disturbance		
-1	Minor intensity		NOTE: Storms which did not occur in the Red Tide area are not included here.
-2	Moderate intensity		
-3	Great intensity		
Year	Date	Type of storm	Remarks
1901	Aug 10-11	H-1	"... reaching southern Florida on the 10th. It passed into the Gulf south of Tampa on the early morning of the 11th..." *
1902	0		
1903	Sep 12	H-1	"... During the 12th the storm moved across Florida into the Gulf ..." near Tampa ... *
1904	Sep	T-1	"... crossed southern Florida ..." *
	Oct 14	T-1	"... caused high winds over southern Florida on the 14th ..." *
	Nov 12	H-2	"... Progressing slowly northward, the storm increased in intensity ..." entered peninsula at Tampa at 8 a.m. ..." *
1905	0		
1906	Jun 16	H-2	"... Crossing southeast Florida on the 17th ... winds reaching a velocity of 70 miles an hour from the northeast at Sand Key on the 16th ... it was attended by heavy rains ..." *
	Oct 18	H-2	"... It passed Key West at 3 a.m. of the 18th, wind 54 miles an hour ... at Sand Key the wind reached 75 miles an hour northwest on the 18th ..." *
1907	0		
1908	0		
1909	Oct 11	H-3	"... and on the 11th approached the Florida Straits ... It recurved over the extreme southern tip of Florida, at which time it had attained tremendous force. The station (at Sand Key) was abandoned at 8:30 a.m. ... The wind was then 75 miles an hour; shortly thereafter ... the wind was estimated at 100 miles an hour. At Key West ..." *
1910	Oct 17-19	H-3	"... swept over the State from Oct. 17th to 19th, doing much damage in some southern counties. Key West reported a wind velocity of 100 miles an hour." ** *
1911	0		
1912	0		
1913	0		
1914	Oct 24-27	T-1	entered peninsula about Fort Myers, traveling north-eastward ... *
1915	Sep 4	H-1	"The storm center struck the coast near the mouth of the Apalachicola River ..." *
	Sep 29	H-3	"... approaching sufficiently near to control the weather over the section (west coast) for several days." ** *

Year	Date	Type of storm	Remarks
1916	Nov 15	H-1	"... moved rapidly northeastward over southern Florida..." *
1917	0		
1918	0		
1919	Sep 9-10	H-3	"... It passed near Key West ... at Sand Key ... Center of the storm passed over Dry Tortugas..." *
1920	Sep 29-30	T-1	"... moved northeastward over the peninsula with the lowest reported pressure at Tampa..." **
1921	Oct 25-26	H-2	"... the tide at Tampa was 10.5 feet... the barometer fell ... the lowest of record..." *
1922	Sep 17	T-1	"... moved from the Gulf into Florida near Tampa and into the Atlantic..." *
1923	0		
1924	Sep 15	H-1	"... Apalachicola..." **
	Sep 29	H-1	"... approached the coast somewhat to the east of Sep 15 storm..." **
1925	Nov 30- Dec 1	H-1	"... Crossing the Florida Peninsula ... (Fort Myers area to the east)" *
1926	Sep 18-19	H-3	"... the center crossed the state from Miami to a point in the vicinity of Cape Romano on the west coast ... dangerous winds prevailed southward to Key West ... portions of Monroe and Lee counties ..." (entire Red Tide area apparently affected by storm) **
1927	0		
1928	Aug 9-10	T-2	Traveled northwestward across the state, moving along the Gulf coast from Tampa area to east of Apalachicola.*, **
	Aug 12-13	T-2	"... moved north and east of Key West ... thence along the west coast ... crossed the coastline of the section to the east of the Apalachicola River..." *
	Sep 16-17	H-3	"... to the north of Tampa ..."; not particularly severe in the Red Tide area, though of great intensity at Lake Okeechobee. **
1929	Sep 28-30	H-3	"... The center passed over Key Largo on the 28th ... wind estimated at 150 miles an hour. At Long Key the barometer fell to 28.18 inches. At Everglades the wind was estimated at 100 miles an hour ... the storm reached Panama City on the 30th..." *
1930	Sep 9	T-2	"... crossed central Florida (entered at Tampa) moving northeastward. It was of small force..." *
1931	Sep 6-8	T-1	"... It moved westward ... southern Florida..." **
1932	Aug 30	T-1	"... in the west coast counties northward to Pinellas ... somewhat to the south of Everglades ... damage ... was confined almost entirely to ... south of latitude 27 degrees..." **
	Sep 14-15	T-1	"... moderate gales ... from Apalachicola to Cedar Keys..." **

Year	Date	Type of storm	Remarks
1933	Jul 30-31	T-3	"... center apparently passing . . . a little north of Punta Gorda . . ." **
	Sep 3-6	T-2	"... moved in a direction between west-northwest and northwest . . . over the west coast the winds were not so high, Tampa recording a maximum of 46..." **
	Oct 4-5	T-2	"... southeast of Key West . . ." **
1934	0		
1935	Sep 2-4	H-3	"... to the Florida Keys. At Long and Matecumbe Keys it was attended by a storm wave which reached a height variously estimated at 15 to 20 feet above mean low water. After leaving the Keys, the storm skirted the Florida Gulf Coast . . . passed inland at Cedar Keys . . ." *
	Nov 4-8	H-2	"... over the Everglades of extreme southern Florida . . . passed into the Gulf near Cape Sable . . . dying out over the eastern Gulf on Nov 8th . . . no dangerous winds were reported from the Gulf coasts . . ." **
1936	Jun 15	T-2	"... about 20 miles south of Ft. Myers at 1 a.m. . . . traveling east-southeastward . . ." **
	Jul 28-30	H-1	"... crossed the extreme southern tip of Florida, passing into the Gulf south of Everglades City . . . moved in a general northwestward direction across the Gulf . . . Boca Grande section . . . north of Punta Gorda . . . Cedar Keys to Apalachicola . . ." **
	Sep 28	T-1	"... passing into the Gulf just south of Tampa . . . moved northwestward and again crossed the coastline near Apalachicola . . ." **
1937	Jul 29-30	T-2	"... crossed the west coastline over Pinellas and northern Hillsborough counties . . . the storm was of small area and very brief . . ." **
	Aug 29-30	T-1	Entered peninsula north of Tampa*
1938	Oct 23-24	T-1	"... moved from the Gulf of Mexico northeastward across Florida north of Tampa . . ." **
1939	Aug 11-12	T-2	"... to Tarpon Springs . . . and reached the coast in the Apalachicola . . . Valpariso section . . ." **
1940	0		
1941	Oct 5-6	H-1	"... crossed the Everglades and passed into the Gulf between Everglades City and Ft. Myers . . . passed some distance off shore until it reached the coast again at Carrabelle . . ." **
	Oct 19-21	T-1	"... passed inland at Cedar Key . . . then north . . ." **
1942	0		
1943	0		
1944	Oct 18-19	H-2	"... directly over Dry Tortugas and west of Key West during the day, and reached the Florida Gulf coast near Sarasota . . . gusts up to 100 miles per hour at Tampa . . ." **
1945	Jun 23-24	T-1	"... the Gulf . . ." **
	Sep 15-16	H-2	"... Key Largo . . ." Florida Keys to Matecumbe**

Year	Date	Type of storm	Remarks
1946	Oct 7-9	H-1	"... Dry Tortugas ... coast in the Tampa Bay area ... Parts of Punta Gorda and Ft. Myers were also flooded as well as low beaches and islands from Tampa Bay to the Keys ..." **
1947	Sep 17-18	H-3	"... moved on a westward course across the state at about 10 mph and entered the Gulf of Mexico a short distance north of Naples ... Sanibel Light where gusts of 120 mph were noted ... heavy damage ... from Everglades City to Sarasota ... greatest ... Fort Myers-Punta Gorda area ..." **
	Sep 23-25	T-2	"... moved up the west Florida coast and passed inland between Tampa and Cedar Key ..." **
	Oct 11-12	H-1	"... passed over the extreme southern portion of Florida ..." **
	Nov 28	T-1	"... Key West ... Sombrero Light ..." **
1948	Sep 21-22	H-2	"... 122 mph at Boca Chica Airport near Key West ... Everglades City ..." northeastward **
	Oct 5-6	H-2	"... crossed the Keys at Bahia Honda Bridge and Marathon, ... winds well over 100 mph ..." northeastward **
1949	Aug 27	H-1	"... reached the west coast north of Tampa ... turned to northward ..." **
1950	Sep 3-6	H-2	"... between Key West and Dry Tortugas ... moved north-northwestward parallel to the West Florida Coast 30 to 50 miles offshore ... reached the coast a little south of Cedar Keys ... St. Petersburg-Clearwater area ... Tampa Bay ..." **
1951	Oct 2	T-2	"... from near Fort Myers to Vero Beach ... flooding rains ... Naples, Fort Myers and Punta Gorda on the west coast ..." **
1952	Feb 2-3	T-1	"... moved across the southern portion of the State from the Naples-Everglades area ..." **
1953	Oct 9	T-3	"... moved into Florida via Charlotte Harbor between Fort Myers and Punta Gorda ..." **
1954	0		
1955	0		

disturbances. Many years (for example, 1906) in which there have been tropical disturbances have been years with no report of Red Tide, and many years (for example, 1912) in which there have been no tropical disturbances have also been years with no report of Red Tide. Similarly, Red Tide outbreaks have occurred in years of much tropical disturbance (for example, 1947) and in years of no tropical disturbance (for example, 1954). Also, many years with tropical disturbances have been followed by years with no Red Tide reported, clearly indicating the lack of a time-lag factor.

THE RELATIONSHIP BETWEEN RED TIDE OUTBREAKS AND
PRECIPITATION

The precipitation data used below have been extracted from publications of the USWB and the Florida State Board of Conservation Division of Water Survey and Research.

Possible correlations between Red Tide outbreaks and some type of precipitation data have been discussed by authors at least since 1890 (Aggasiz). Slobodkin (1953) investigated stations with the heaviest rainfall at times of reported outbreaks. Ingle and de Sylva (1955) discussed the connection between plankton blooms and rainfall over adjacent land areas. However, even though these and others

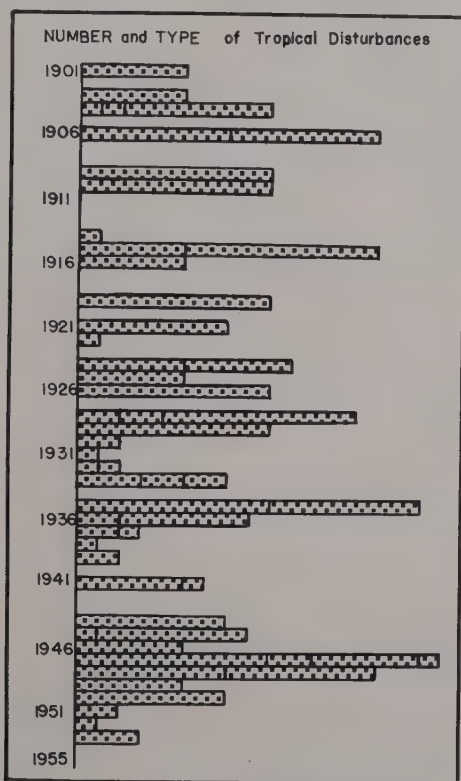


FIGURE 2. Number and Type of Tropical Disturbances 1901-1955.

TABLE 3
FLORIDA PRECIPITATION
Data recorded to nearest 0.1 inch

A Calendar year total															
B Water year total															
C "Rainy season" total															
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	A	B	C
1891	2.0	1.6	3.6	2.9	2.7	6.0	6.5	5.7	7.8	4.3	2.0	2.6	47.7	—	33.0
1892	3.4	1.4	1.6	0.8	2.2	9.0	4.8	8.2	9.7	3.9	0.8	2.8	48.6	50.0	37.8
1893	1.9	4.1	5.6	2.4	3.9	7.7	5.1	6.9	6.4	4.4	2.8	3.2	54.4	51.5	34.4
1894	2.2	3.0	1.9	1.2	2.3	6.1	8.3	7.4	13.0	3.8	3.0	1.2	53.4	55.8	40.9
1895	3.4	3.3	2.5	4.7	4.4	4.3	7.4	5.9	4.6	3.3	2.8	1.7	48.3	48.5	29.9
1896	4.1	3.0	2.6	0.5	2.8	10.7	8.1	5.8	4.3	3.2	3.7	2.2	51.0	49.7	34.9
1897	1.9	6.1	2.1	4.5	2.3	5.0	7.1	6.7	11.0	4.4	1.8	2.8	55.7	55.8	36.5
1898	0.7	2.1	1.3	1.4	1.6	3.2	8.9	12.9	5.2	6.3	2.3	4.1	50.0	46.3	38.1
1899	4.7	5.9	1.9	3.5	1.1	5.5	9.1	6.6	5.0	6.2	0.8	2.0	52.3	56.0	33.5
1900	3.3	4.4	6.8	4.5	4.0	9.6	7.4	4.4	4.4	5.6	1.3	4.5	60.7	58.3	35.9
1901	2.4	4.3	5.4	2.2	4.3	9.8	6.3	10.6	8.2	1.9	0.9	2.6	58.9	64.9	41.1
1902	0.7	4.8	4.4	1.4	2.4	5.9	5.2	4.7	9.5	5.6	3.2	3.7	51.5	44.4	33.3
1903	5.2	5.6	5.4	0.4	4.9	6.7	6.5	6.8	7.4	1.9	2.8	1.8	55.4	61.4	34.2
1904	5.2	3.1	1.6	1.7	2.5	6.3	6.2	7.4	4.4	4.7	3.0	1.9	48.0	44.9	31.5
1905	1.7	3.4	3.9	2.5	5.6	4.9	7.9	11.6	7.7	2.9	0.9	7.4	60.4	58.8	40.6
1906	4.6	2.8	3.2	1.2	7.0	7.7	9.6	7.4	5.3	3.1	1.2	1.1	54.2	60.0	40.1
1907	0.8	1.4	0.6	3.5	4.9	6.1	7.7	6.0	8.4	1.6	2.4	5.9	49.3	44.8	34.7
1908	3.3	2.3	0.7	3.3	2.7	6.1	6.6	6.9	9.4	3.4	1.9	1.0	47.6	51.2	35.1
1909	1.7	1.8	2.8	2.8	4.2	6.4	11.1	7.6	4.1	2.0	0.9	2.7	48.1	48.8	35.4
1910	1.4	3.4	1.9	1.2	2.5	9.9	7.6	8.6	3.1	9.0	1.9	1.1	51.6	45.2	40.7
1911	1.3	0.2	2.2	2.1	4.5	4.6	6.2	8.9	3.9	5.3	4.1	4.6	47.9	45.9	33.4
1912	5.5	3.2	4.0	4.5	5.7	11.8	5.7	5.8	9.9	4.2	2.9	2.3	65.5	70.1	43.1
1913	1.9	4.8	5.6	2.0	3.1	5.3	5.4	6.8	5.9	2.9	1.0	3.5	48.2	50.2	29.4
1914	4.3	5.1	1.6	2.3	1.7	4.0	6.0	5.6	7.3	4.0	3.0	4.4	49.3	45.3	28.6
1915	5.6	3.8	2.6	1.2	6.1	5.1	7.2	6.8	5.0	7.5	2.6	2.6	56.1	54.8	37.7
1916	1.2	1.2	0.9	2.3	3.9	6.3	8.3	6.0	4.9	4.1	3.7	5.0	47.8	47.7	33.5
1917	1.5	1.8	2.0	1.5	2.7	5.1	6.6	7.7	7.6	2.6	0.6	1.5	41.2	49.3	32.3
1918	3.1	0.8	2.5	5.7	2.4	5.1	5.5	5.8	6.3	5.8	3.5	3.8	50.3	41.9	30.9
1919	2.4	4.9	5.4	2.4	6.5	7.1	8.8	6.8	4.7	2.5	3.3	2.8	57.6	62.1	36.4
1920	2.7	5.5	1.3	6.3	5.0	6.0	7.1	6.6	8.0	1.8	4.1	3.5	57.9	57.1	34.5
1921	1.4	1.8	2.0	2.1	5.6	3.5	8.4	4.4	2.1	8.6	2.7	2.3	44.9	40.7	32.6

TABLE 3—(continued)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	A	B	C
1922	2.3	3.0	2.5	0.9	7.5	6.3	6.7	8.0	7.5	8.0	1.5	3.0	57.2	58.3	44.0
1923	1.9	1.7	2.2	2.4	9.0	8.9	7.0	6.8	4.5	3.5	0.9	1.5	50.3	56.9	39.7
1924	4.2	3.3	6.0	3.3	3.2	6.2	9.7	4.2	8.6	10.1	0.5	2.5	61.8	54.6	42.0
1925	5.1	2.1	1.9	1.5	5.6	6.0	7.1	6.6	2.4	3.5	4.0	5.9	51.7	51.4	31.2
1926	5.9	2.4	4.4	4.5	2.7	7.8	9.4	8.2	7.9	2.7	3.2	1.1	60.2	66.6	38.7
1927	0.4	3.6	2.4	1.3	0.9	7.2	7.0	6.2	3.9	3.7	1.2	3.0	40.8	39.9	28.9
1928	0.8	3.2	4.5	7.8	3.6	6.8	7.4	9.6	11.5	3.2	0.7	1.5	60.6	63.1	42.1
1929	3.3	2.2	3.5	3.6	4.9	7.8	8.2	6.4	10.7	4.0	1.7	3.0	59.3	56.0	42.0
1930	3.8	3.0	7.5	3.3	3.9	10.3	4.5	4.2	8.7	2.6	3.7	4.2	59.7	57.9	34.2
1931	3.4	2.2	5.2	4.3	3.3	2.1	5.9	6.3	4.7	2.2	0.5	3.2	43.3	47.9	24.5
1932	2.6	1.1	3.7	1.3	6.1	8.4	3.7	9.8	6.4	4.4	4.5	1.1	53.1	49.0	38.8
1933	2.5	3.5	3.9	7.5	2.5	5.0	10.1	6.5	7.1	4.5	1.6	0.7	55.4	58.6	35.7
1934	1.5	3.9	3.5	4.1	6.7	9.9	7.3	5.5	4.2	3.8	1.6	1.1	53.1	53.4	37.4
1935	1.5	2.7	1.1	4.2	3.8	5.0	9.2	9.0	9.2	2.3	1.5	2.8	52.3	52.2	38.5
1936	5.6	6.7	3.3	2.2	4.1	7.9	6.5	6.8	4.5	5.5	1.5	3.0	57.6	54.2	35.3
1937	1.8	5.0	4.3	5.0	3.4	5.7	6.9	8.8	7.2	4.9	4.3	1.3	58.6	58.1	36.9
1938	2.1	1.4	1.9	1.3	4.1	6.7	8.4	3.8	5.8	4.7	1.6	1.4	43.2	46.0	33.5
1939	1.6	2.3	1.5	4.3	5.0	9.1	7.6	10.8	5.7	2.9	1.4	2.2	54.4	55.6	41.1
1940	2.6	4.6	3.5	2.8	2.0	6.9	8.4	6.9	6.6	0.8	1.3	6.0	52.4	50.8	31.6
1941	3.4	3.6	3.9	4.2	1.5	7.8	10.1	5.2	6.2	5.5	3.4	4.1	58.9	54.0	36.3
1942	3.8	4.6	6.1	2.8	3.5	10.3	4.9	5.4	6.7	1.2	0.7	3.4	53.4	61.1	32.0
1943	1.8	0.8	4.3	2.2	5.0	6.3	8.1	7.1	6.4	2.5	1.9	1.7	48.1	47.3	35.4
1944	2.5	1.7	5.7	4.1	2.9	5.2	9.3	7.8	6.1	5.8	1.6	0.8	53.5	51.4	37.1
1945	3.9	1.3	0.7	3.2	2.0	7.7	10.1	8.4	8.4	3.8	1.1	5.1	55.7	53.9	40.4
1946	2.9	2.6	4.3	1.3	7.8	6.8	9.1	6.8	6.9	2.7	2.8	1.0	55.0	58.5	40.1
1947	2.6	3.6	6.9	5.1	4.8	8.7	8.0	7.1	10.4	6.9	5.8	2.8	72.7	63.7	45.9
1948	5.0	1.1	7.1	4.6	2.4	3.8	10.8	7.7	9.9	4.9	2.6	2.9	62.8	67.9	39.5
1949	1.0	2.7	2.2	5.2	2.3	7.5	7.9	11.1	7.6	3.7	1.9	2.4	55.5	57.9	40.1
1950	0.4	1.0	4.0	3.1	3.1	3.7	7.9	6.3	8.0	7.1	0.9	2.9	48.4	45.5	36.1
1951	0.9	1.9	3.2	4.2	2.5	4.7	7.3	5.5	7.2	4.7	4.1	2.6	48.8	48.3	31.9
1952	1.2	5.6	3.9	2.1	3.8	3.3	5.4	7.5	6.4	6.6	1.1	1.4	48.3	50.6	33.0
1953	3.4	3.4	3.0	6.4	1.6	7.9	7.6	9.5	10.5	5.5	3.6	5.9	68.3	62.4	42.6
1954	1.0	2.0	2.4	3.5	4.6	5.7	7.6	4.6	6.6	3.2	3.0	1.7	45.9	53.0	32.3
1955	2.6	2.0	1.6	2.4	2.9	6.3	7.0	5.5	6.0	3.3	1.4	1.4	42.4	44.2	31.0
Mean	2.7	3.0	3.3	3.1	3.8	6.6	7.5	7.1	6.9	4.2	2.2	2.8	53.2	53.3	36.1

have noted the possibility of such correlations, there is a lack of assembled data and objective analysis. For this reason, the author decided to explore the problem quantitatively.

The hypothesis adopted, that either precipitation in Florida as a whole, or precipitation in the Peace River Drainage Basin can be used as an indicator for subsequent Red Tide outbreaks, was further refined to consider individually the effects of the annual precipitation, the water-year precipitation (October - September), and the "rainy season" precipitation (May - October).

Precipitation data for Florida (Table 3) were taken directly from Table 1 of the USWB Monthly Climatological Summaries, Comparative Data, 1955. These data have been weighted according to area by the Weather Bureau. Precipitation data for the Peace River Drainage Basin (Table 4) were obtained by taking the arithmetic mean of the amounts of precipitation reported by all weather stations in the area. These data were taken from the Florida State Board of Conservation Division of Water Survey and Research, Paper No. 11 and Supplement until 1952, and from USWB publications since then.

When the intensities of Red Tide outbreaks as given above are assumed, the coefficient of linear correlation between Red Tide outbreaks and annual precipitation in Florida from 1891 through 1955 is 0.15; between Red Tide outbreaks and water-year precipitation in Florida for the same period is 0.12; between Red Tide outbreaks and "rainy season" precipitation in Florida for the same period is 0.18. The three coefficients are in the range of no significance. Similarly, the coefficient of linear correlation between Red Tide outbreaks and annual precipitation in the Peace River Drainage Basin from 1936 through 1955 is 0.42; between Red Tide outbreaks and water-year precipitation in the Peace River Drainage Basin for the same period is 0.44; between Red Tide outbreaks and "rainy season" precipitation in the Peace River Drainage Basin for the same period is 0.29. These three coefficients are also in the range of no significance.

This negation of the hypothesis does not eliminate the possibility that Red Tide outbreaks may be indirectly related to either precipitation in Florida or precipitation in the Peace River Drainage Basin. Multiple correlations are currently in progress. When these have been completed, it may be possible to differentiate the indirect role of precipitation in a Red Tide outbreak.

TABLE 5
APALACHICOLA RUNOFF
Data recorded to the nearest thousand "second-foot-day"

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1934-35	440	260	328	373	388	851	621	450	267	342	362	380	5062
1935-36	219	279	300	1937	1883	1016	2165	622	386	435	763	351	10356
1936-37	646	365	768	1259	1151	1158	1327	1071	495	489	476	529	9734
1937-38	477	535	524	538	397	596	1535	548	458	594	499	288	6989
1938-39	254	231	269	365	762	1476	938	650	654	522	823	526	7470
1939-40	384	274	315	600	1058	938	796	477	392	994	454	311	6993
1940-41	223	291	416	519	406	591	503	305	214	434	345	227	4474
1941-42	216	192	581	986	878	1646	959	515	590	508	558	388	8017
1942-43	377	329	511	1398	918	1946	1057	752	512	536	471	293	9100
1943-44	261	298	341	627	692	1722	2421	1319	521	485	476	466	9629
1944-45	328	289	416	486	839	826	581	859	375	483	464	437	6383
1945-46	383	419	827	1814	1077	1127	1228	1182	830	640	748	452	10727
1946-47	404	396	370	1025	631	1384	1357	888	747	621	534	360	8717
1947-48	322	793	1266	916	1373	2013	1834	630	526	1174	907	513	12267
1948-49	566	847	2182	1417	1490	1174	1089	1215	691	966	733	592	12962
1949-50	439	399	472	498	503	838	648	481	483	372	352	432	5917
1950-51	279	264	364	443	370	504	729	421	286	308	252	219	4439
1951-52	224	335	637	590	848	1825	953	618	508	287	306	291	7422
1952-53	223	217	360	754	785	987	891	1394	469	703	440	403	7626
1953-54	526	336	1330	1057	651	756	645	411	326	332	259	190	6837
1954-55	165	180	273	436	544	396	580	378	237	386	339	205	4119

TABLE 6
PEACE RIVER RUNOFF
Data recorded to the nearest thousand "second-foot-day"

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1931-32	20	4	3	3	3	3	2	5	17	7	19	84	170
1932-33	12	5	4	3	4	4	7	4	17	66	50	30	206
1933-34	35	13	8	6	6	10	13	27	130	78	68	72	466
1934-35	26	6	5	4	3	3	3	3	3	29	29	144	258
1935-36	39	9	10	35	140	87	16	6	27	29	29	47	474
1936-37	52	13	8	6	22	16	64	28	14	48	38	45	354
1937-38	32	18	37	17	8	6	3	3	25	68	38	12	267
1938-39	110	26	10	7	5	3	3	4	142	150	179	172	811
1939-40	48	15	7	18	41	29	23	5	9	65	48	83	391
1940-41	34	4	6	23	23	17	49	8	14	103	38	44	363
1941-42	14	20	20	49	40	73	26	14	97	87	20	29	489
1942-43	11	4	5	5	4	11	4	5	29	148	123	99	448
1943-44	59	10	7	6	4	7	4	4	9	19	59	35	223
1944-45	21	14	6	13	6	3	3	2	47	205	107	109	536
1945-46	69	19	14	14	9	16	4	5	7	63	83	61	364
1946-47	34	13	7	6	13	59	50	15	131	124	148	279	879
1947-48	105	38	31	51	42	22	14	7	55	31	113	155	664
1948-49	164	17	14	10	7	5	5	3	24	43	195	157	644
1949-50	123	21	12	12	7	6	4	5	5	6	11	44	256
1950-51	66	17	14	11	11	7	53	13	6	49	69	48	364
1951-52	68	21	16	10	14	25	19	8	9	23	29	33	275
1952-53	149	51	21	32	36	21	32	7	78	63	123	228	841
1953-54	216	64	96	49	21	18	17	24	104	94	46	59	808
1954-55	42	18	16	15	15	8	7	4	6	19	29	81	260

THE RELATIONSHIP BETWEEN RED TIDE OUTBREAKS AND
RIVER RUNOFF

The runoff data used below have been extracted from publications of the United States Geological Survey. River runoff (Tables 5 and 6) is recorded to the nearest thousand "second-foot-day," where one "second-foot-day" is equal to a runoff of 86,400 cubic feet of water in one day.

Chew (1953), Odum (1953), Lasker and Smith (1954) and others have mentioned the possible relationship between Red Tide outbreaks and river runoff, although a quantitative study has not been included in the literature.

The Peace River is located geographically quite near the center of the Red Tide area. The runoff of the Apalachicola River (almost 17 times that of the Peace River and greater than the combined runoffs of all the rivers on the west coast of Florida) seems to retain its identity *at least* as far south as Tampa Bay at some seasons (Chew, unpublished manuscript). Therefore, the hypothesis that either the runoff of the Peace River or the runoff of the Apalachicola River or the combined influence of these runoffs is a factor in Red Tide outbreaks, was formulated.

Using the data of Table 1 as the Red Tide factor, the coefficient of linear correlation between Red Tide outbreaks and annual runoff of the Peace River for the period 1931-32 through 1954-55 is 0.24; the coefficient of linear correlation between Red Tide outbreaks and annual runoff of the Apalachicola River for the period 1934-35 through 1954-55 is 0.26. Both coefficients are outside the range of significance. The coefficient of linear multiple correlation, measuring the relationship between Red Tide outbreaks and the combined effect of the runoffs is 0.46, also in the range of no significance. The coefficient of linear multiple correlation of Red Tide outbreaks with Apalachicola River runoff, Peace River runoff, and Florida (water-year) precipitation is 0.46, in the range of no significance.

While these ambient phenomena, as treated above, indicate no connection with Red Tide, it does not suggest that, when differently formulated, or in combination with other, as yet unconsidered factor, they may not prove to have some connection with the Red Tide.

TABLE 7

INCIDENCE OF "RED TIDE" OUTBREAKS FROM FEBRUARY, 1954
THROUGH FEBRUARY, 1955.SOURCES: * University of Miami Marine Laboratory Mimeographed Report
No. 55-15

United States Fish & Wildlife Service, Naples

† Other

Source	Date	Location(s)
* 1954	2-4	Boca Grande
*	2-10	Boca Grande Inlets
*	2-18	Boca Grande
*	2-28	Redfish Pass; Captiva Pass
#, *	3-11	Fort Myers Beach; San Carlos Bay; Big Carlos Inlet; Estero Is. and
#	3-12	Fort Myers Beach; San Carlos Bay
*	3-17	Captiva
*	3-31	San Carlos Marina
*	4-7	Captiva
*	4-11	Boca Grande (20-30 miles offshore); Boca Grande Pass
#	4-12	Sarasota to Egmont Key
*	4-28	Boca Grande to Venice; Big Pass; Anna Maria Key
*	4-30	Boca Grande
*	5-1	Boca Grande
#	5-2	240° off Johns Pass
*	5-3	Boca Grande (3 miles offshore; 8 miles offshore)
*	5-6	Stump Pass
*	5-7	Boca Grande Pass
*	5-8	Gasparilla Yacht Lagoon
#	5-19	Sanibel—Captiva (Blind Pass)
#	5-20	Sanibel—Captiva (Blind Pass)
*	5-27	Boca Grande
*	5-28	New Pass
*	5-29	Pine Island Sound
#	6-1	Pine Island Sound to Boca Grande
*	6-7	Boca Grande
#, *	6-13	Egmont Key to Indian Rocks; Sanibel (Tarpon Bay)
#, *	6-14	Egmont Key to Indian Rocks; Sanibel (Tarpon Bay)
#	7-21	Longboat Key to Anna Maria Key (12 miles offshore)
#	7-28	Wiggins Pass
#	7-29	Wiggins Pass
#	7-30	Wiggins Pass; Big Carlos Pass and Beach
*, #	8-5	240° from Johns Pass; Crescent Beach to Siesta Key
*	8-12	Longboat Key to Venice (8 miles out to the beach)
*, #	8-13	Longboat Key to Venice (8 miles out to the beach); Vanderbilt Beach to Wiggins Pass
#	8-14	Vanderbilt Beach to Wiggins Pass
#	8-15	Vanderbilt Beach to Wiggins Pass
#	8-16	10 miles off St. Petersburg
*	8-17	St. Petersburg Beaches
*	8-18	Boca Grande
*	8-19	Boca Grande
*	8-20	Boca Grande

Source	Date	Location(s)
*	8-21	Boca Grande
#	8-22	Boca Grande
*	8-23	Venice to Sarasota (½ to 5 miles offshore)
*	8-24	Venice to Sarasota (½ to 5 miles offshore)
*	8-25	Venice to Sarasota (½ to 5 miles offshore)
*	8-26	Venice to Sarasota (½ to 5 miles offshore)
*	8-27	Venice to Sarasota (½ to 5 miles offshore)
#	9-10	Siesta Key; Longboat Key
*, #	9-11	Bradenton Beach; Longboat Key; Siesta Key
#	9-12	Siesta Key
#, *	9-20	Sarasota Bay; 18 miles off Clearwater
*	9-23	Longbeach, Longboat Key; Buttonwood Harbor, Longboat Key
*	9-24	Longbeach, Longboat Key; Buttonwood Harbor, Longboat Key
*	9-25	Longbeach, Longboat Key; Buttonwood Harbor, Longboat Key
*	9-26	Buttonwood Harbor, Longboat Key
*	9-27	Buttonwood Harbor, Longboat Key
*	9-28	Buttonwood Harbor, Longboat Key; Sarasota area
*	9-29	Buttonwood Harbor, Longboat Key
#	10-6	Naples Pier to Gordon's Pass; Clam Pass
*	11-27	Gasparilla Pass
*	12-1	Boca Grande
*	12-4	Gasparilla Pass
*	12-5	Gasparilla Pass
*	12-30	Coxambas Pass to Marco (8 to 10 miles offshore)
* 1955	2-1	Off Sanibel lighthouse

TABLE 8

INCIDENCE OF POST-OUTBREAK PHENOMENA FROM FEBRUARY, 1954 THROUGH FEBRUARY, 1955.

SOURCES: * University of Miami Marine Laboratory Mimeographed Report No. 55-15

United States Fish & Wildlife Service, Naples. † Other.

Source	Date	Location(s)
† 1954	2-8	Boca Grande
#	2-10	Captiva to Boca Grande
#	2-25	Sanibel (Tarpon Bay)
*	3-13	San Carlos area
*	3-16	Sanibel lighthouse; Captiva
*	3-29	5 miles south of Sanibel lighthouse; Big Pass to Fort Myers Beach
*	3-30	Captiva and Sanibel; San Carlos Marina
*	4-1	Captiva and Sanibel
*	4-2	Big Sarasota Pass to Midnight Pass
†	4-11	Nokomis
†	4-12	Nokomis
†	4-13	Nokomis
†	4-14	Nokomis

Source	Date	Location(s)
†,*	4-15	Nokomis; Boca Grande Pass
*	4-24	Venice Inlet
#	4-26	Boca Grande; Gasparilla Island; Englewood
#,*	4-28	Venice to Englewood (Manasota Bay); Boca Grande
*	4-30	Captiva
*	5-2	Redfish Pass
*	5-6	Marco to Naples Beach; Lemon Bay
*	5-16	Redfish Pass
*	5-18	San Carlos Bay
*	5-22	New Pass
*	5-23	New Pass
*	5-26	New Pass
#	5-27	Vanderbilt Beach to Naples
#	5-28	Vanderbilt Beach to Naples
*	5-30	Pine Island Sound
*	7-4	Naples to Sarasota (15 to 25 miles offshore)
*	7-21	Sarasota (40 to 45 miles offshore)
#	8-4	260° off Longboat Key (23 miles out)
#	8-5	10 miles off St. Petersburg
#	8-6	Off Longboat Key
*	8-9	½ to ¾ miles north of Midnight Pass
*	8-10	Sarasota—Bradenton area
*,#	8-11	Sarasota to Venice
*	8-12	Passage Key Inlet (8 to 10 miles west); Longboat Pass (3 miles out to the beach)
*	8-13	Passage Key Inlet (8 to 10 miles west); Longboat Pass (3 miles out to the beach)
*	8-15	Longboat Key
*	8-19	Sarasota area
*	8-30	Manasota Key
*	8-31	Manasota Key
*	9-6	Bradenton Beach
*	9-12	Longboat Key
*	9-15	Bradenton Beach, Anna Maria Key
*	9-16	Anna Maria Key
*	9-21	Off Clearwater
*	9-22	Off Clearwater
#	10-12	Boca Grande
*	10-13	Bradenton Beach
#,*	10-15	Indian Rocks Beach; Bella Vista Beach
#	10-16	Mullet Key
*	10-20	20 miles out from Tampa Bay
†	11-1	Siesta Key; Crescent Beach
*	11-3	Siesta Key
*	11-18	South of Hurricane Pass to Knight's Pass; Bonita Beach
*	11-19	South of Hurricane Pass to Knight's Pass; Bonita Beach
*	11-20	South of Hurricane Pass to Knight's Pass
*	11-21	South of Hurricane Pass to Knight's Pass; Stump Pass, Punta Gorda Beach
*	11-22	South of Hurricane Pass to Knight's Pass; Englewood
*	11-27	Boca Grande (back bayou)
*	12-5	All around Boca Grande

SOME POSSIBLE PATTERNS OF MOVEMENT OF RED TIDE PHENOMENA, WITH REFERENCE TO A SERIES OF RED TIDE INCIDENCE REPORTS AND A TENTATIVE CURRENT PATTERN.

Reported Red Tide outbreaks from February, 1954 through February, 1955 (Table 7) and reported "aftermath phenomena" for this period (Table 8) are shown in a schematic drawing (Figure 3) plotted against areas of the Red Tide region of the west coast of Florida as defined in Table 9 and Figure 4. Figure 3 indicates areas III, VI, and VII had the greatest number of outbreaks and "aftermath phenomena" during this period. The southern areas were affected during the cooler

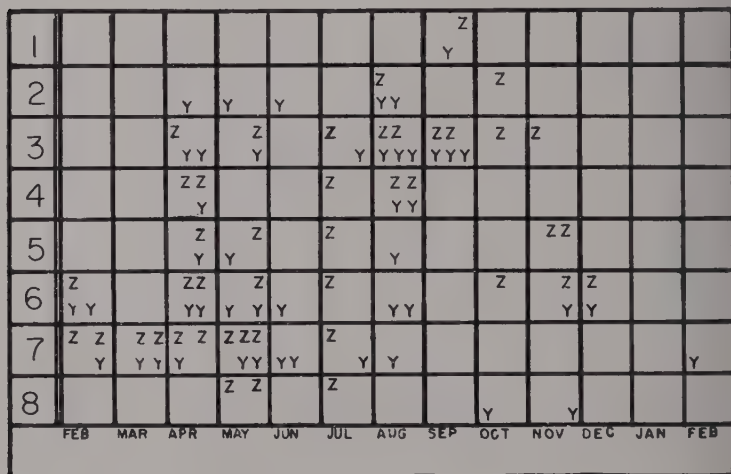
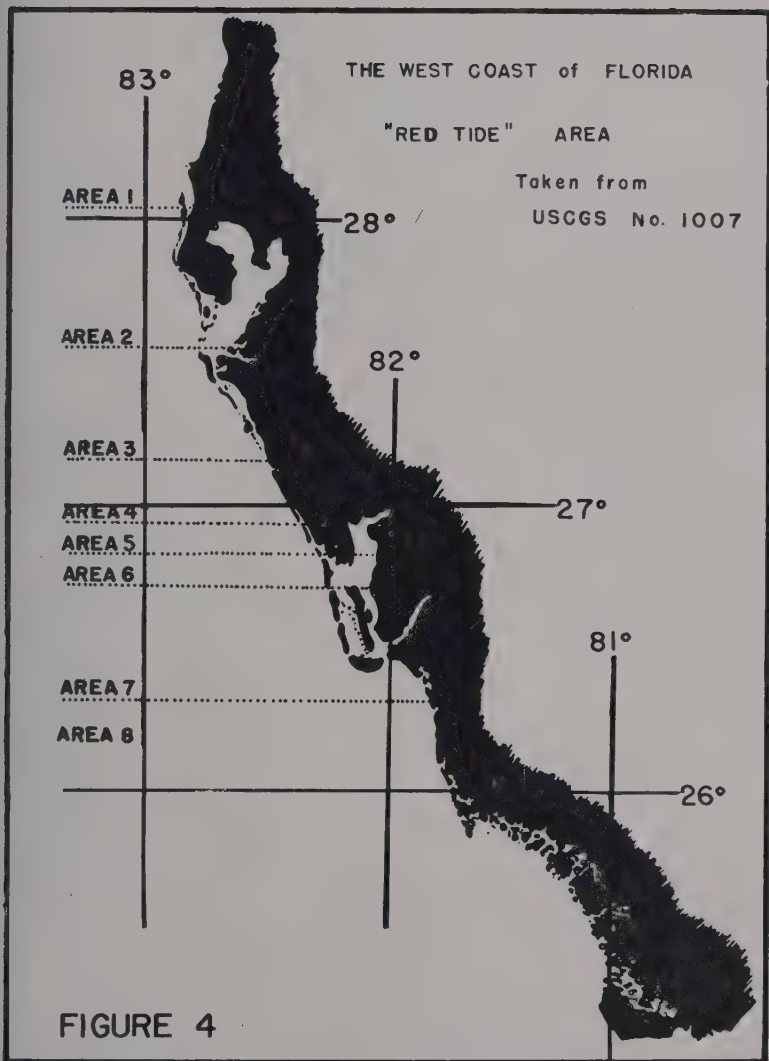


FIGURE 3. Red Tide phenomena in space and time.

TABLE 9
AREAS OF WEST COAST OF FLORIDA.

Area Number	Extent of Area
1	North of Little Pass
2	Passage Key Inlet to Little Pass
3	Midnight Pass to Passage Key Inlet
4	Lemon Bay to Midnight Pass
5	Little Gasparilla Pass to Lemon Bay
6	Boca Grande Pass to Little Gasparilla Pass
7	Little Carlos Pass to Boca Grande Pass
8	South of Little Carlos Pass



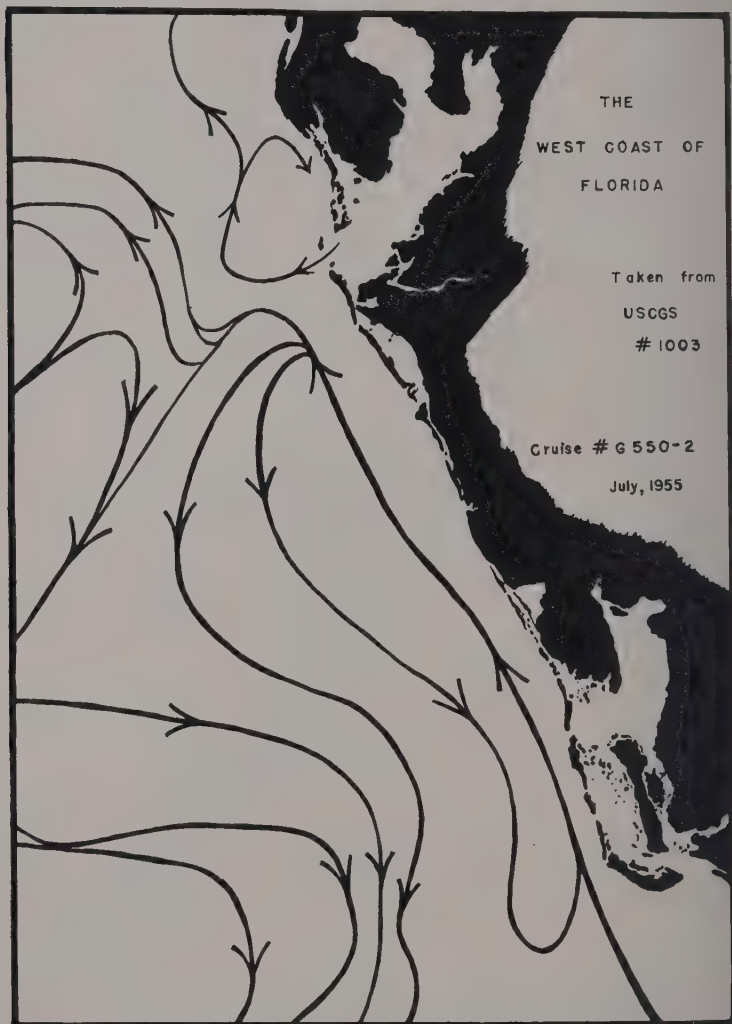


FIGURE 5. A tentative current pattern for the eastern Gulf of Mexico, in the Red Tide area.

months, while the northern areas, particularly area III, experienced the most severe attacks in August and September. Areas II - VII appear to be most susceptible to Red Tide in August. Areas I and VIII have rarely reported Red Tide outbreaks.

Figure 5 shows a tentative current pattern for the principal area affected by Red Tide, based on data amassed in July, 1955, on Cruise No. G 550-2 of The Marine Laboratory of the University of Miami. Superimposed on this mean current are those currents caused by tidal forces, turbulence, and wind stress. Due to the rotation of the earth, a pure wind drift current is generally deflected to the right of the wind in this hemisphere. In an area close to the shoreline, the wind drift movements, as well as other current components, are further complicated by the coastal topography. The north bound current is relatively narrow, with ill-defined boundaries. While it is obvious that Red Tide phenomena are borne in a general northerly direction by the currents, particularly during the warmer months, it is also obvious that the exact pattern of movement of a given Red Tide outbreak cannot be determined from these data alone. Even with increased knowledge of the currents and the behavior of the varying components, it will not be possible to predict the detailed movements of an outbreak until outbreaks of Red Tide are more accurately reported in space and time. Until such time, only general discussion is possible. To increase the probability of detailed, accurate reporting, The Marine Laboratory of the University of Miami has established a network of observers along the west coast of Florida. These individuals examine the water daily for signs of Red Tide outbreaks in their sectors, and submit weekly detailed reports of normal and abnormal conditions.

CONCLUSIONS

1. An examination of an apparent pattern of Red Tide outbreaks forms the basis for a tentative long range "prediction."
2. An attempt to correlate Red Tide outbreaks with tropical disturbances shows that there is no apparent linear relationship between these phenomena.
3. Although simple linear correlations of Red Tide outbreaks and precipitation and runoff data, are too low to be of significance, the possibility that an indirect relationship may exist is under consideration.
4. More accurate reporting of individual Red Tide phenomena in space and time is necessary, so that information on currents, tides,

etc. which is available, may be utilized to predict possible paths of outbreaks.

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A CONTRIBUTION TO THE LIFE HISTORY OF THE FISH, *BREGMACEROS ATLANTICUS* GOODE AND BEAN, FROM THE FLORIDA CURRENT¹

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ABSTRACT

Forty-eight postlarval, juvenile and adult specimens of *Bregmaceros atlanticus* Goode and Bean, ranging from 3.1 to 57.8 mm standard length, predominantly from the Florida Current are described and ten are illustrated. Spawning, changes in development, and general biology are discussed.

INTRODUCTION

This paper is one of a series of contributions from the Marine Laboratory, University of Miami, devoted to the study of life histories of the pelagic fishes of the Florida Current. This work has been carried out as part of the National Geographic Society-Marine Laboratory, University of Miami Pelagic Fish Life History Program, under the direction of Gilbert L. Voss.

Since 1950 a total of 39 postlarval, juvenile, and adult specimens of *Bregmaceros atlanticus* Goode and Bean, 1886, (sometimes called the unicorn fish) have been obtained in the Straits of Florida off Miami. The fishes of the family Bregmacerotidae are small, and are widely distributed throughout the tropical and subtropical waters of the Western Atlantic, the Pacific and Indian Oceans, and the China Sea. The family consists of one genus with 4 or 5 species or subspecies (Parr, 1926). Since Goode and Bean described *B. atlanticus*, little concerning this species has been added to the literature, and no records of postlarval and juvenile specimens have been found by the author.

The genus *Bregmaceros* is represented by two species in the Florida area. The most noticeable difference between these two species is the presence or absence of rays between the first and second dorsal fins. *B. cayorum* Nichols, 1952 has been recorded from the Florida Keys. According to Nichols *B. cayorum* has no rays between the first and second dorsals, and only a few short rays between the two anal fins. *B. atlanticus* has rays between the dorsals and anals. These

¹Contribution No. 141 from the Marine Laboratory, University of Miami.

TABLE 1
NG and SL Station Data

Station	Date	Location	Depth M.	Time	Temp. °C.	Sal. ‰	Illum.*	No. of Spec.
NG 6B	9/12/50	25°43'-26°08'N. 79°56'W.	91	1151	24.49	36.51	—	2
11A-1	12/9/50	24°03.5'N. 82°04.1'W.	492	1834	—	—	—	1
14D	1/12/51	25°43'-26°08'N. 79°56'W.	90	1242	—	—	—	1
14E	1/12/51	"	194	1416	—	—	—	1
16-7	1/28/51	25°46'-25°51'N. 79°49'W.	38	some- time between 1459- 1739	24.04	36.20	10 ⁻⁰	1
16-18	1/28/51	"	243	2239	—	—	10 ⁻⁸	1
16-24	1/29/51	"	218	0201	10.57	35.80	10 ⁻⁸	1
16-34	1/29/51	"	192	0910	11.93	35.97	10 ⁻⁶	1
18A	1/29/51	25°43'N. 79°31'W.	0	2338	—	—	almost none	1
25C	5/25/51	25°43'-26°08'N. 79°56'W.	130	1220	20.6	36.25	—	1
29A	7/13/51	"	31	0900	26.1	36.34	—	1
29C	7/13/51	"	119	0955	16.1	35.56	—	1
32-38	8/15/51	"	75	0730	22.3	—	10 ⁻⁰	1
39D	2/4/52	"	97	1138	22.0	36.22	—	2
39G	2/4/52	"	146	1225	16.1	35.85	—	1
SL 10C-0	12/9/52	"	0	2145	—	—	almost none	1
10C-6	12/10/52	"	214	0000	—	—	—	1
11A-1	1/22/53	"	46	1850	24.70	36.21	10 ⁻⁶	1

*See Moore (1950)

TABLE 1—(Continued)

Station	Date	Location	Depth M.	Time	Temp. °C.	Sal. ‰	Illum.	No. of Spec.
SL 13A-6	2/26/53	25°35'N. 79°25'W.	—	1825	—	—	—	1
15A-2	4/23/53	"	91	2020	25.50	36.08	10 ⁻⁸	1
15A-5	4/23/53	"	274	1900	17.34	36.20	10 ⁻¹²	1
16C-2	5/22/53	"	110	1550	25.80	36.24	10 ⁻⁴	1
18A-2	7/1/53	"	119	2210	—	—	almost	1
19B-2	8/13/53	"	91	2027	—	—	none	1
19B-3	8/13/53	"	640	2138	—	—	10 ⁻¹⁰	1
19E-2	8/14/53	"	91	1127	—	—	almost	1
23A-2	12/10/53	"	91	2002	25.40	36.64	none	2
23A-6	12/10/53	"	731	1657	7.9	35.08	10 ⁻¹⁰	1
23D-7	12/11/53	"	640	1335	9.2	35.40	10 ⁻²²	1
32B-1	2/1/55	25°35'N. 79°25'W.	91	0050	23.90	—	10 ⁻¹⁶	1
32B-2	1/31/55	"	155	2355	22.15	—	almost	2
33A-4	2/23/55	"	358	0935	16.25	—	none	1
34B-2	4/1/55	"	194	0035	20.08	36.02	10 ⁻¹⁴	1
35D-2	4/29/55	25°43'N. 79°56'W.	43	0855	24.30	36.44	10 ⁻⁸	1
36A-1	5/9/55	25°31.5'N. 80°01.5'W.	50	1555	24.50	—	10 ⁻¹²	1
							10 ⁻²	1
							10 ⁻⁰	1

dorsal and anal rays were found in every specimen after the continuous fin fold stage; therefore, the author considers all the bregmacerotids contained in this study to be *B. atlanticus*.

The author wishes to thank The Marine Laboratory staff, particularly David O'Berry and the captains and crews of the R/V PHYSALIA and T-19 for the material collected by the Laboratory. She also wishes to thank Dr. Leonard P. Schultz of the United States National Museum for the loan of 9 supplementary bregmacerotids from the Bermudas and Florida. In addition, the author is indebted to Gilbert L. and Nancy A. Voss for their suggestions, advice, and useful criticisms given throughout the preparation of this paper, and to Miss Anita Feinstein for her statistical aid.

MATERIALS AND METHODS

Stations.

The major portion of the material studied was obtained by the Marine Laboratory. This material was supplemented by specimens collected by the R/V ATLANTIS of the Woods Hole Oceanographic Institution and the Cuban hydrographic vessel YARA. Complete station data are given in Table 1.

Collection of material.

The plankton nets used in the collection of the Marine Laboratory material were 70 cm diameter Discovery type closing nets. When the weather was favorable, the stations covered a 24 hour period. Nine nets spaced 100 meters apart, with the first at the surface, were lowered in a series of four flights. Throughout the 24 hours, usually five of these series of flights were completed. The remaining stations were occupied around noon and midnight, and the flights of these stations averaged five net hauls. The total number of hauls and the depths at which these were taken are given in Figure 8. and it may be seen from this graph that a greater number of samples was taken in the top 150 meters. Each plankton sample was preserved in 10 per cent formalin buffered with borax.

Along with the plankton samples, fathometers, bathythermographs. Nansen reversing thermometers, secchi discs, photocells, and depth-distance recorders were used to collect raw hydrographic data. From these, data were calculated including depth, average time of flight, temperature, salinity, and light penetration for each haul. For greater detail of methods of collection, see Miller *et al.* (1953) and Voss (1954).

Terminology.

The terms used herein are those defined by Hubbs (1943) and employed by Voss (1954).

MEASUREMENTS

A micrometer eyepiece was used in taking the measurements of the smaller specimens, while dividers were used for the larger fish. All measurements and counts were made on the left side unless the left side of a particular fish was damaged.

Standard length—tip of the upper jaw to caudal base.

Snout length—tip of upper jaw to the inside of the anterior rim of the bony orbit.

Head length—tip of upper jaw to most posterior margin of the operculum.

Orbit diameter—greatest interior measurement of horizontal diameter of the bony orbit.

Greatest depth—a vertical measurement at any point anterior to the origin of the anal fin.

Pre-cephalic length—tip of upper jaw to the base of the pre-cephalic appendage.

Pre-dorsal length—tip of upper jaw to origin of first dorsal fin.

Pre-anal length—tip of upper jaw to origin of first anal fin.

Maxillary and *mandibular* lengths are self explanatory.

The lengths of the cephalic appendage, longest pelvic, anterior and posterior dorsal and anal fin rays, are listed in Table 2. At first glance, the dorsal and anal fins each appear to be continuous. However, both of these fins are actually divided into groups, i.e., first dorsal and second dorsal fins, with undeveloped short rays found between these. It is difficult to distinguish a break between the two anterior groups, especially in the early stages. The fin count is listed (Table 4) in three sections: anterior developed rays + undeveloped rays + posterior developed rays. If the distinction between the first two sections is not clear, these are listed as one number, first dorsal developed and undeveloped rays + second dorsal developed rays. A tuft or group of tufts are seen at the base of the pelvic fin of more developed specimens. The tuft(s) is given in parentheses after the pelvic count.

All measurements were made in millimeters. All indices are given as percentages of standard length.

TABLE 2
Length of longest fin rays (in mm) of 45 specimens of
Bregmaceros Atlanticus from the Straits of Florida.

Source	Std. L. mm	Cephalic Appendage	First Dorsal	Second Dorsal	First Anal	Second Anal	Pelvic
SL 33A-4	3.1	0.25	—	—	—	—	0.06
SL 11A-1	3.2	2.1	—	—	—	—	0.08
SL 35D-2	4.0	0.70	—	—	—	—	1.00
SL 36A-1	4.8	1.55	0.20	—	0.40	0.20	damaged
NG 14E	4.9	0.90	—	—	—	—	0.50 +
SL 10C-0	5.2	1.7	0.20	—	0.50	0.30	1.45
NG 32-38	5.2	1.2	0.20	—	0.50	damaged	1.4
SL 19E-2	5.5	0.1 +	0.20	0.40	0.60	0.25	1.4
SL 23D-7	5.8	0.7 +	0.30	0.20	0.55	0.30	2.1
NG 29A	5.9	0.7 +	0.20	0.20	0.30	0.20	2.4
NG 39D	5.9	0.8 +	0.40	0.20	0.30	0.20	1.6 +
SL 32B-1	5.9	0.3 +	0.25	0.25	0.45	0.30	1.3 +
NG 18A	6.7	0.2 +	—	—	—	—	1.4 +
SL 19E-2	7.1	2.4	0.35	0.30	0.90	0.70	2.0
NG 16-34	7.1	1.1 +	0.40	0.30	0.80	0.50	1.8
SL 10C-6	7.6	2.7	0.60	0.30	1.05	0.70	1.7
NG 11A-1	8.1	2.5 +	0.80	0.50	1.2	0.70	2.7
NG 16-24	8.4	1.0 +	0.80	0.60	0.90	0.50	2.8
SL 15A-5	8.5	0.7 +	0.50	0.30	1.1	0.40	3.0
NG 29C	8.6	1.5 +	—	—	—	0.50	2.5

TABLE 2—(Continued)

NG 39D	9.0	0.70 +	0.80	0.50	0.90	0.70	3.0
NG 25C	10.2	0.25 +	1.0	0.80	1.25	0.60	4.0
NG 6B	11.5	1.7 +	1.3	0.65	1.6	1.0	6.2
SL 19B-3	11.7	3.0	1.1	1.1	1.6	1.0	5.0
NG 16-18	11.8	2.4 +	1.2	0.40 +	1.5	0.9	4.5
NG 16-7	11.9	2.5 +	—	—	2.2	0.9	5.5
SL 15A-2	13.0	2.5 +	1.4	1.0	2.1	1.1	6.1
SL 16C-2	13.9	1.3 +	1.6	0.80	2.3	1.0	7.1
SL 13A-6	14.5	2.5	1.9	0.90	2.0	1.1	7.0
NG 39G	15.0	2.7	2.0	1.1	1.5	1.2	5.7
SL 34B-2	15.0	damaged	—	—	—	—	damaged
USNM 89920	19.4	3.3	2.8	1.0	3.7	1.7	9.4
USNM 143114	20.9	3.7	2.0	1.6	2.3	1.5	8.0
SL 19B-2	21.0	4.0	3.4	1.9	3.1	0.7	10.2
USNM 153150	22.7	4.7	3.5	1.4	4.5	1.5	11.5
SL 18A-2	22.9	5.1	3.5	1.7	3.7	1.0	11.0
SL 32B-1	25.4	5.0	3.5	1.6	4.2	1.75	13.2
SL 23A-2	28.1	5.0	4.0	1.9	4.9	1.2	12.5
SL 23A-6	33.5	6.4	5.8	1.7	6.5	2.1	17.2
USNM 116837	36.3	8.5	6.3	2.6	7.0	2.2	17.5
USNM 116837	37.5	8.0	6.2	3.0	6.9	2.4	15.4
USNM 116837	40.7	8.4	8.0	3.2	7.3	2.6	19.4
USNM 116837	49.6	12.0	8.5	2.7	10.5	3.7	24.0
USNM 116837	51.5	11.7	10.2	2.8	9.2	3.9	24.5
USNM 116837	57.8	13.1	9.6	3.5	10.5	2.8	27.1

DEVELOPMENT

Specimens Studied.

Twelve specimens (4.9-11.5 mm standard length), (two of which were too damaged for measurements), from seven NG stations. Complete data given in Table 5.

Twenty-two specimens (3.1-33.5 mm standard length), from thirteen regular SL stations. Complete data given in Table 5.

One specimen (8.1 mm standard length), YARA, station No. 39 (NG 11). Complete data given in Table 5.

Four specimens (7.1-11.9 mm standard length), ATLANTIS (NG 16). Complete data given in Table 5.

One specimen, USNM No. 89920 (19.4 mm standard length), station No. 321, 1929, 33°50' N., 63°55' W.

One specimen, USNM No. 143114 (20.9 mm standard length), "Steamer FISH HAWK, 189," station No. 7123, April 2, 1901, 121 meters, 26°33' N., 83°10' W.

One specimen, USNM No. 153150 (22.7 mm standard length), TRITON station No. 9, January 7, 1950, 137 meters off Palm Beach, Florida.

Six specimens USNM No. 116837 (36.3-57.8 mm standard length), June 18, 1926, 37-73 meters, south of Bird Key, Dry Tortugas, Florida.

Development of the Young.

The postlarvae of *B. atlanticus* are distinguished by the presence of the cephalic appendage, presence of a continuous dorsal fin fold or fin, head shape, rather long pelvic rays (except in the earliest stages), and by the dorso-lateral position of the pectoral fin. At the ventral angle of the pre-operculum, a definite broad spine is evident. A characteristic arrangement of the pigmentation patches on the body is present throughout the earlier postlarval stages.

The proportions and fin counts of all the described specimens are given in Tables 3 and 4, respectively. Probably due to methods of preservation, the NG specimens are lacking in pigment. This possibly is due to the fact that some of these specimens have not been stored in the dark and to the weakness of the formalin in which they were preserved (see Orton, 1955).

At 3.2 mm (Fig. 1a), chromatophores are found in the head region, at the interorbital space, post-dorsal to the eye, and post-ventral to the mouth. On the body, chromatophores are found immediately posterior to the head, along the gut region, and posterior to the pectoral fin. Four distinct patches are found immediately dorsal to the anal fin fold, and two patches are ventral to the dorsal fin fold. The cephalic appendage is situated above the origin of the pectoral, and, at this stage, it is quite long in proportion to the

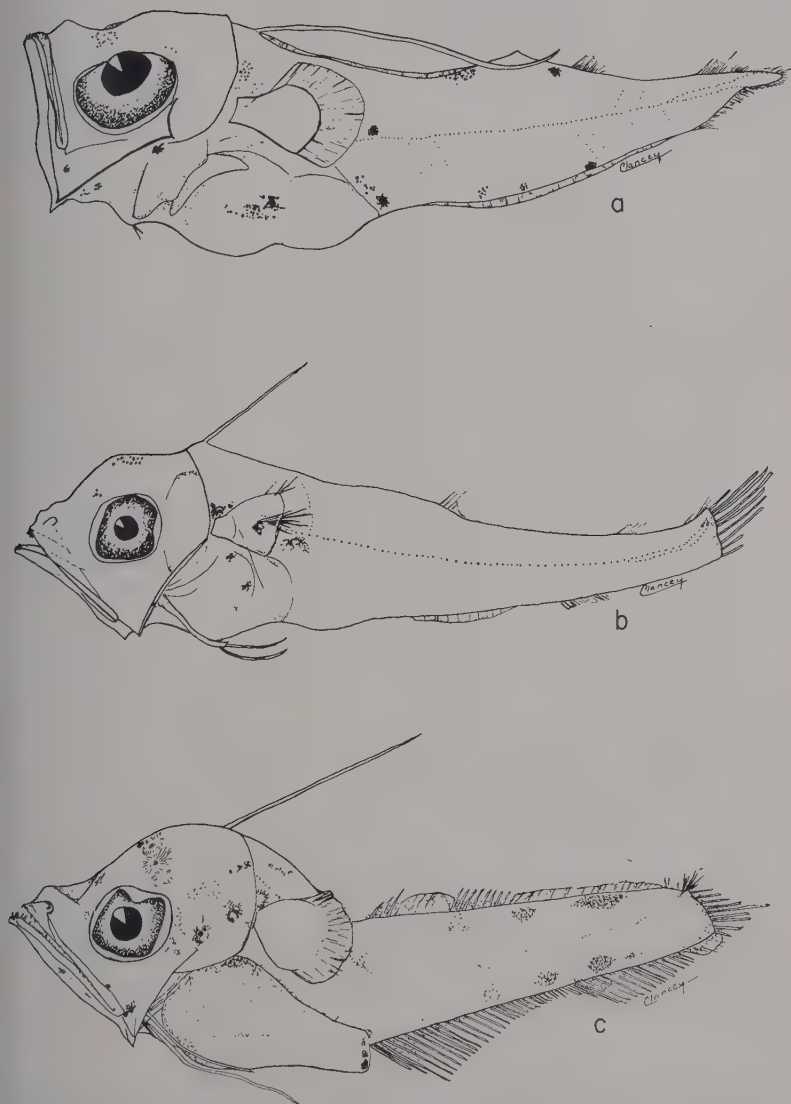


FIGURE 1. *Bregmaceros atlanticus* Goode and Bean. Postlarval specimens.
a. 3.2 mm standard length; b. 4.9 mm standard length; c. 5.2 mm standard length.

TABLE 3
Bodily Proportions of 45 specimens of *Bregmaceros atlanticus* from
the Straits of Florida.

Source	Std. L, mm	Snout Index	Head Index	Mandibular Index	Maxillary Index	Orbit Index	Pre-cephalic Index	Pre-first Dorsal Index	Pre-first Anal Index	Depth Index
SL 33A-4	3.1	6.5	31.0	19.0	17.4	14.0	—	48.1	48.4	—
SL 11A-1	3.2	4.7	28.1	17.2	15.6	14.1	31.3	46.9	53.1	34.4
SL 35D-2	4.0	7.5	28.8	18.8	18.8	12.5	31.3	47.5	50.0	30.0
SL 36A-1	4.8	7.4	29.5	17.9	20.0	9.5	28.4	45.3	47.4	34.7
NG 14E	4.9	7.1	24.5	17.4	19.4	11.2	28.6	59.2	57.1	26.5
SL 10C-0	5.2	7.7	30.8	19.2	19.2	13.5	32.7	48.1	51.9	34.6
NG 32-38	5.2	5.8	25.0	17.3	19.2	9.6	26.9	44.2	44.2	26.9
SL 19E-2	5.5	6.4	27.3	14.6	16.4	10.9	27.3	41.8	47.3	30.9
SL 23D-7	5.8	7.0	27.8	14.8	16.5	10.4	24.4	47.0	45.2	26.1
NG 29A	5.9	8.6	29.1	16.2	17.1	12.0	29.1	46.2	53.0	27.4
NG 39D	5.9	8.6	29.1	15.4	17.1	12.0	29.1	47.0	47.0	23.9
SL 32B-1	5.9	6.8	26.5	15.4	16.2	12.0	28.2	47.0	48.7	28.2
NG 18A	6.7	4.5	19.4	16.4	17.2	9.0	22.4	46.3	50.8	23.9
SL 19E-2	7.1	4.2	23.9	14.1	15.5	8.5	21.1	40.9	50.7	31.0
NG 16-34	7.1	7.1	23.9	15.5	16.9	9.9	23.9	42.3	46.5	21.1
SL 10C-6	7.6	7.9	27.6	14.5	16.5	7.2	26.3	46.1	46.7	25.0
NG 11A-1	8.1	6.2	24.7	13.6	14.8	7.4	29.6	44.4	49.4	33.3
NG 16-24	8.4	7.1	23.8	13.1	15.5	7.1	22.6	47.6	39.3	16.7

TABLE 3—(Continued)

SL 15A-5	8.5	5.9	24.7	15.3	16.5	8.2	22.4	41.2	45.9	23.5
NG 29C	8.6	5.9	23.4	11.7	13.5	8.8	21.1	38.6	44.4	15.2
NG 39D	9.0	5.0	24.4	12.8	13.3	6.1	25.6	40.0	41.1	26.1
NG 25C	10.2	5.4	21.6	11.8	12.8	6.9	17.7	39.2	39.7	18.6
NG 6B	11.5	4.4	20.4	11.3	11.7	5.2	19.1	42.6	46.1	22.2
SL 19B-3	11.7	6.0	23.9	12.8	13.3	6.4	21.4	41.9	41.0	23.9
NG 16-18	11.8	5.5	22.9	10.2	10.6	6.8	18.6	41.5	40.7	15.3
NG 16-7	11.9	5.9	20.2	10.9	11.8	6.7	17.7	46.2	46.2	16.0
SL 15A-2	13.0	5.4	18.5	10.4	10.8	6.2	19.2	43.1	40.0	18.5
SL 16C-2	13.9	4.3	22.3	10.8	11.5	6.1	16.6	38.9	43.2	22.3
SL 13A-6	14.5	4.1	20.7	9.0	9.7	5.5	17.9	42.8	40.7	16.6
NG 39G	15.0	4.7	19.3	7.3	8.7	4.7	16.0	42.0	40.0	14.0
SL 34B-2	15.0	4.7	21.0	—	—	6.0	16.7	—	—	—
USNM 89920	19.4	3.6	19.6	7.2	10.3	5.2	16.0	40.2	37.1	12.4
USNM 143114	20.9	3.8	18.2	6.7	8.1	4.8	13.4	40.7	41.2	14.4
SL 19B-2	21.0	3.1	17.1	8.6	9.5	4.3	16.7	36.7	33.3	14.8
USNM 153150	22.7	4.4	20.3	7.5	9.3	4.9	14.1	43.2	41.4	13.7
SL 18A-2	22.9	4.2	17.5	8.3	8.7	4.4	14.9	41.1	37.1	13.5
SL 32B-1	25.4	2.6	17.0	5.3	6.5	4.3	14.2	38.4	36.2	12.8
SL 23A-2	28.1	2.9	18.2	6.8	7.1	4.3	13.9	36.3	36.3	14.6
SL 23A-6	33.5	3.0	16.3	4.5	6.6	7.2	15.1	36.7	34.6	17.9
USNM 116837	36.3	2.5	17.1	5.5	8.0	5.5	13.8	41.9	42.4	16.5
USNM 116837	37.5	3.7	18.9	6.4	8.5	5.6	13.3	39.7	40.8	16.0
USNM 116837	40.7	4.2	16.0	6.1	8.9	5.9	12.8	40.3	41.3	17.0
USNM 116837	49.6	3.4	19.0	7.1	8.1	6.3	13.5	39.9	45.2	17.7
USNM 116837	51.5	4.1	18.3	6.8	7.8	5.2	12.6	41.8	40.4	16.3
USNM 116837	57.8	3.5	15.6	5.0	7.6	5.5	11.4	31.1	29.4	14.7

TABLE 4
Fin Counts of 48 specimens of *Bregmaceros atlanticus* from
the Straits of Florida.

Source	Std. L. mm	First Dorsal	Second Dorsal	First Anal	Second Anal	Pectoral	Pelvic	Caudal
SL 33A-4	3.1	0	0	0	0	0	3	0
SL 11A-1	3.2	0	0	0	0	0	2	0
SL 35D-2	4.0	0	0	0	0	0	3	0
SL 36A-1	4.8	15	0	23	14	0	3	0
NG 14E	4.9	—	—	—	—	0	3	9
SL 10C-0	5.2	11	0	18	20	0	3	9
NG 32-38	5.2	5 + x	0	14	—	0	3	—
SL 19E-2	5.5	30	15	16 + 7	18	0	3	20
SL 23D-7	5.8	12 + x + 7	15	16 + 4	18	0	3	30
NG 29A	5.9	6 + x	15	14 + x	x + 8	0	3	16
NG 39D	5.9	11 + x	15	5 + x	x + 9 + x	0	3	14
SL 32B-1	5.9	23	19	a total of	42	0	3	10
NG 18A	6.7	—	—	—	—	0	3(1)	20
SL 19E-2	7.1	11 + 6	16	14 + 9	15	0	3(1)	30
NG 16-34	7.1	12 + x + 3	16 +	12 + x	16	0	3(1)	24
SL 10C-6	7.6	15 + 14	16	23	19	0	3(1)	19
NG 11A-1	8.1	15 + 11	16	18 + 6	18	0	3(1)	30
NG 16-24	8.4	11 + x + 2	16	18 + x	17	0	3(1)	24
SL 15A-5	8.5	15 + 7	16	26	21	2	3(1)	23

TABLE 4—(Continued)

NG 29C	8.6	—	—	—	18	2	3(1)	26
NG 39D	9.0	15 + 11	16	18 + 11	17	0	3(1)	30
NG 25C	10.2	14 + x + 7	17	18 + 10	18	4	3(1)	18 +
NG 6B	11.5	13 + 3 + x	8 +	19 + x	5 +	10	3(1)	—
SL 19B-3	11.7	15 + 7	15	16 + 15	18	5	3(1)	30
NG 16-18	11.8	15 + 10	16	18 + 5	22	11	3(1)	26
NG 16-7	11.9	—	—	18 + 8	16	—	3(2)	23 +
SL 15A-2	13.0	15 + 7	16	18 + 7	22	7	3(2)	32
SL 16C-2	13.9	15 + 12	16	18 + 7	20	8	3(4)	26
SL 13A-6	14.5	14 + 7	16	18 + 8	19	9	3(4)	32
NG 39G	15.0	14 + 7	18	18 + 9	18	11	3(4)	29
SL 34B-2	15.0	—	—	—	—	—	3	—
USNM 89920	19.4	15 + 12	16	16 + 11	20	15	3(3)	34
USNM 143114	20.9	14 + 9	16	17 + 8	18	17	3(4)	30
SL 19B-2	21.0	15 + 13	19	19 + 13	22	17	3(4)	30
USNM 153150	22.7	15 + 9	17	17 + 10	20	17	3(3)	30
SL 18A-2	22.9	15 + 14	16	18 + 13	18	16	3(4)	30
SL 32B-1	25.4	15 + 13	19	18 + 13	23	17	3(3)	34
SL 23A-2	28.1	16 + 11	18	17 + 19	24	16	3(3)	30
SL 23A-6	33.5	15 + 16	17	18 + 12.	20	17	3(1)	30
USNM 116837	36.3	15 + 10	17	18 + 11	18	15	3(2)	30
USNM 116837	37.5	15 + 13	16	13 + 9	21	16	3(3)	32
USNM 116837	40.7	15 + 14	17	18 + 11	20	16	3(3)	30
USNM 116837	49.6	15 + 13	17	18 + 11	20	16	3(3)	30
USNM 116837	51.5	15 + 14	17	19 + 11	21	16	3(3)	32
USNM 116837	57.8	15 + 12	16	15 + 9	20	15	3(3)	30

standard length (65.6%). The first dorsal fin is seen in the fin fold stage, whereas the second dorsal and caudal fins give very slight evidences of ray formation, and the pelvic fin is comprised of two short rays. At this stage, the mouth is nearly vertical, hence the mandible is longer than the maxilla. The eye is large, 14.1% of standard length, and the vertebral column remains straight.

The 4.9 mm postlarva (Fig. 1b) is an NG specimen and lacks much of the characteristic pigmentation. However, it may be mentioned that some chromatophores were seen in the head and abdominal regions and immediately above the abdominal area. The cephalic appendage is slightly anterior to the origin of the torn pectoral fin. Portions of the dorsal and anal fins are torn; therefore, only scattered dorsal and anal filaments and anterior anal fin fold are visible. Nine caudal rays have developed. Three pelvic rays are easily recognizable and these rays are much longer than those of the 3.2 mm specimen. The mouth now tends towards the horizontal, and from this stage forward, the maxilla is always equal to, or slightly longer than the mandible. Teeth are present at the anterior tips of the upper and lower jaws and the snout length is approximately two-fold that of the previous specimen. The eye is characteristically squarish as it is in many larvae, and the urostyle has developed.

The 5.2 mm specimen is shown in Fig. 1c. Pigmentation is more intense in this specimen because the chromatophores postdorsal to the eye have expanded, forming a band which extends across the head, and shows patchiness behind the eye. Chromatophores appear along the upper and lower jaws. Pigmentation of the gut has become more intense and three definite chromatophores are seen near the anus. Chromatophores are present behind the head and posterior to the pectoral fin. The four patches dorsal to the anal fins are larger and more intense than those of the 3.2 mm specimen. The two patches ventral to the dorsal fins now appear as four larger groups. The cephalic appendage is found approximately midway between the posterior margin of the orbit and the origin of the pectoral. The first dorsal is composed of three rays followed by a portion of fin fold, then eight rays. The second dorsal, however, has not developed rays. Advance in growth is seen in the anal fins with a total of thirty-eight rays. The longest ray of the first anal is 0.5 mm; of the second anal, 0.3 mm. Nine caudal rays again are found in this specimen. The snout, eye, and head are similar to the 4.9 mm fish in percentages of standard length. A dorsal snout sinus is

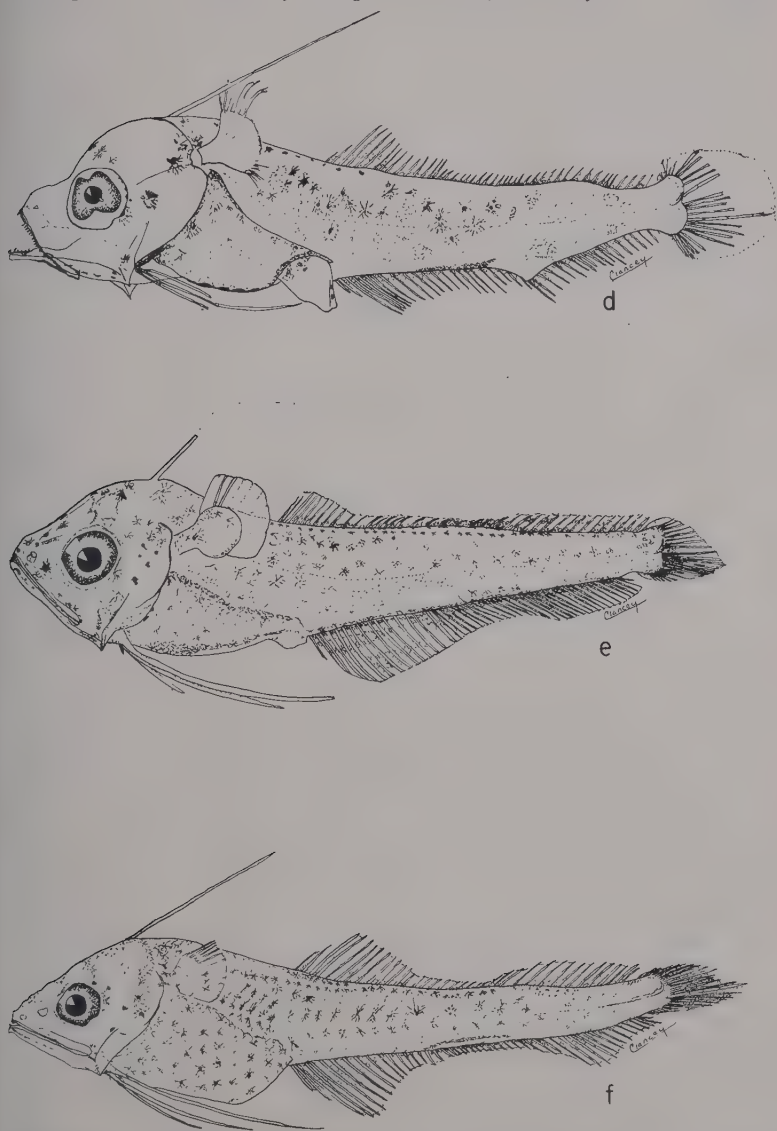


FIGURE 2. *Bregmaceros atlanticus* Goode and Bean. Postlarval specimens. d. 7.6 mm standard length; e. 8.5 mm standard length; f. 11.7 mm standard length.

present and teeth now occur along the upper and lower jaws. This specimen is more robust in appearance than the earlier stages.

Figure 2d shows a specimen measuring 7.6 mm. At this stage the head pigmentation is similar to that of the 5.2 mm specimen. The pigmentation of the gut has intensified, and numerous chromatophores cover the body. A line of melanophores is seen along the anterior portion of the dorsal ridge and slight traces of two of the dorsal patches remain. The four ventral patches are less definite than the 5.2 mm specimen; however, they are still discernible. At 7.1 mm, no traces of the dorsal and anal fin folds remain. The dorsal fins of the 7.6 mm specimen are developed and numbered $15 + 14 + 16$ rays. The first anal cannot be divided accurately into the two groups, but it has twenty-three rays and the second anal has 19. The somewhat rounded caudal fin now has 19 rays, and, at this stage, the first evidence of two rather distinct caudal lobes appears. Evidence of pectoral ray development is seen, but no definite rays are distinguishable. The most interior pelvic ray has a small tuft at its base. This first was observed in the 6.7 mm specimen. The orbit diameter has increased 0.5 mm more than the 5.2 mm specimen.

At 8.5 mm standard length (Fig. 2e), the number of chromatophores has increased and they are scattered throughout the entire specimen. The dorsal fin count is $15 + 7 + 16$; the anal, $26 + 21$. Again, it is difficult to determine the break in the first anal. The caudal fin has lost its roundness and is arrowhead-shaped, composed of twenty-three rays. The pectoral fin is narrower at its base, and signs of two developing rays are seen. Each interiormost ventral ray has one small tuft at its base. The proportion of snout length to standard length has decreased, and the snout has become smoother, and shows a tendency towards pointedness. The eye has become more circular, while the gut has shrunk considerably in comparison with the previous specimen.

At 11.7 mm (Fig. 2f), the body chromatophores seem to follow a definite pattern similar to that of the myotomes. Those of the gut form vertical stripes. Along the dorsal ridge, two rows of chromatophores are seen separated more widely anteriorly, fusing posteriorly. The dorsal fin count is $15 + 7 + 15$; anal, $16 + 15 + 18$. Although the dorsal and anal rays are not as long as in the adult, the general shape of the fins is similar. The caudal rays are 30. Five rays are observable on the dorsal portion of the pectoral. Three tufts are found on the innermost pelvic ray. The snout and head indices

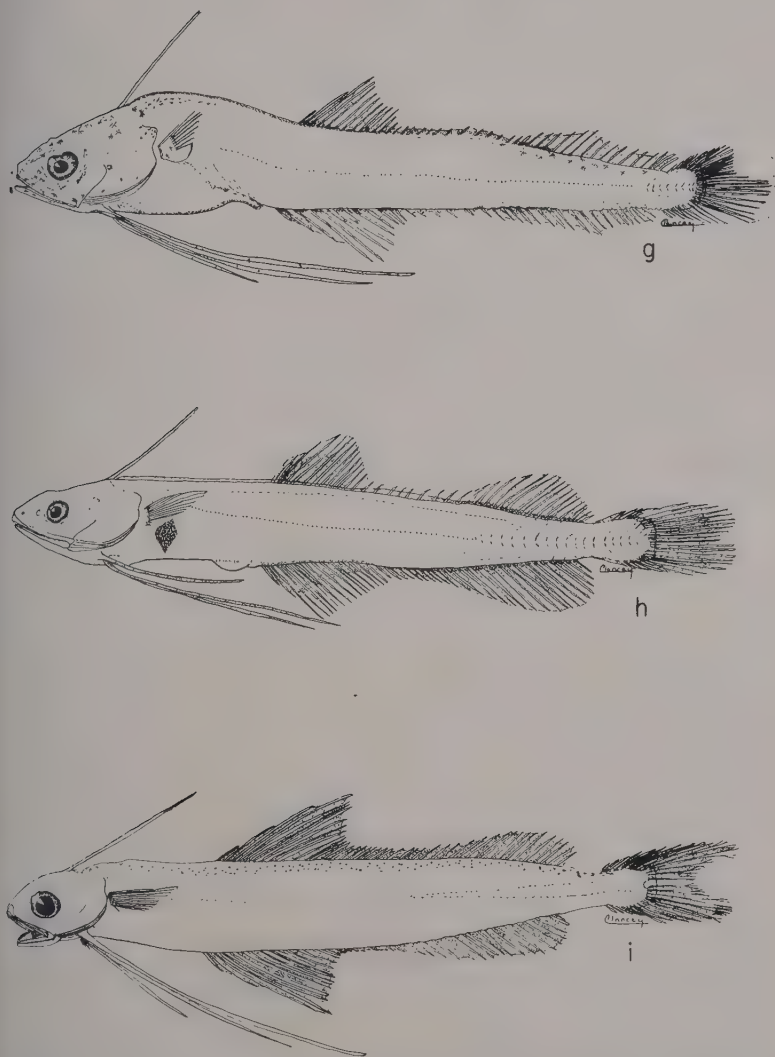


FIGURE 3. *Bregmaceros atlanticus* Goode and Bean. g. Postlarval specimen, 14.5 mm standard length; h. Juvenile specimen, 15.0 mm standard length; i. Adult specimen, 57.8 mm standard length.

are about the same as the previous specimen, but the eye has decreased from 8.2 to 6.4% of the standard length. The snout has become more pointed, and hence the head takes on a more triangular appearance.

It may be seen in Fig. 3g, that the 14.5 mm specimen has acquired many of the adult characters, and at this stage, the fish has a tannish appearance. The dorsal ray count is $14 + 7 + 16$, and the anal, $18 + 8 + 19$. The caudal fin is slightly lobed and consists of 32 rays. The shape of the now mediolateral pectoral fin shows a change between the specimens measuring 13.9 and 14.5 mm. At the latter stage, the fin is roughly triangular in shape and nine rays appear. The longest pectoral ray extends beyond the origin of the anal fin. The body has become much slimmer, the greatest depth being 16.5% of the standard length, and the orbit diameter has decreased from 6.4% in the 11.7 specimen to 5.5% of the standard length in this specimen. The operculum has attained a shape similar to that of the adult. A narrow ridge is seen along the dorsal body ridge, posterior to the cephalic appendage, ending near the origin of the second dorsal. The base of the vertebral column is straight. The roundness of the gut, observed in earlier stages, has nearly disappeared.

At 15.0 mm (Fig. 3h), more intense pigment is seen at the fin bases. A few large head chromatophores remain and these may be seen to occur through to the 22.9 mm specimen. The dorsal fin count is $14 + 7 + 18$; anal, $18 + 9 + 18$. The caudal fin is commencing to fork and consists of 29 rays. The pectoral is broadly lancet-shaped, comprised of eleven fully developed rays with evidence of five more. At this stage the percentage of greatest depth is 14.0%, showing a decrement of 2.6% from the previous specimen. Juvenile stages of many fish are known to be slimmer than the postlarval stages due to the shrinkage of the gut and to the increase in length. This is observed in *B. atlanticus* from 15.0 mm to 28.1 mm, where the proportion of greatest depth to standard length is less (12.4-14.8%) than that observed in smaller or larger specimens. Hence, it is believed that the 15.0 mm fish represents the approximate beginning of the juvenile period. At 15.0 mm, the orbit diameter percentage is less, and the head is shallower than the previous specimen. The dorsal ridge is now quite evident. Another 15.0 mm specimen was studied, but it was too damaged for comparative studies.

At 58.7 mm (Fig. 3i), as in all adults, the cephalic appendage

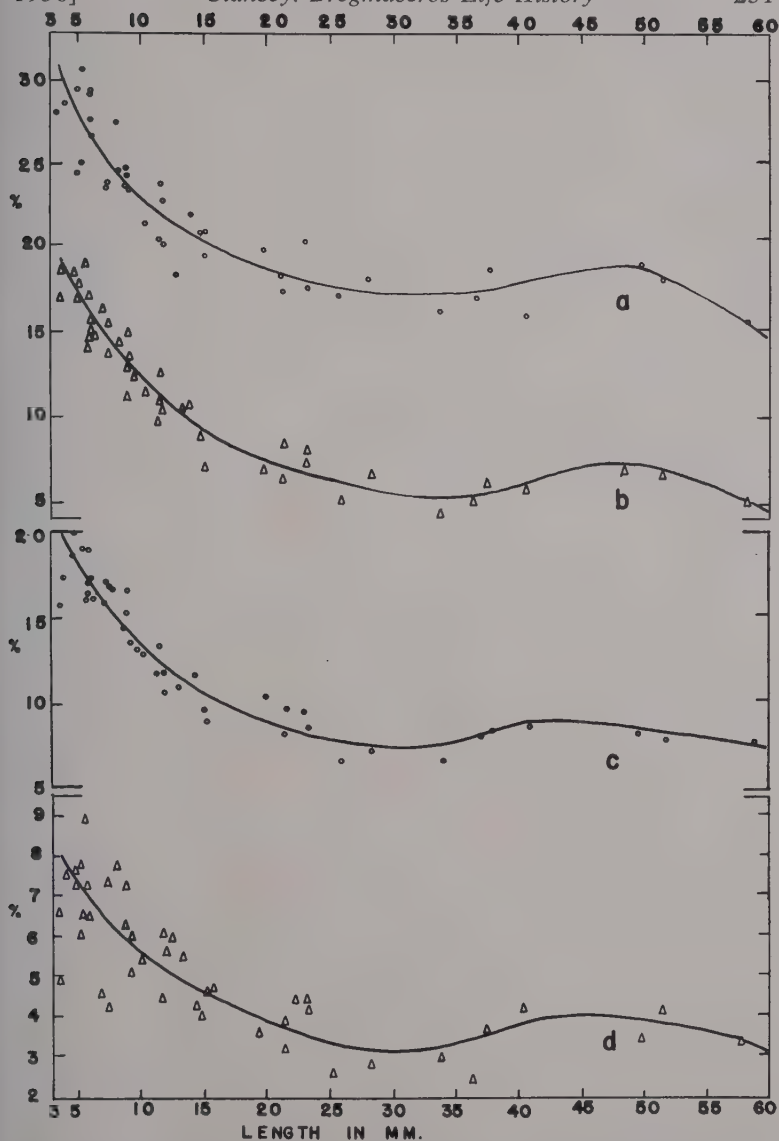


FIGURE 4. *Bregmaceros atlanticus* Goode and Bean. Change of bodily proportions during growth. a. Relationship of head length to standard length. b. Relationship of mandibular length to standard length. c. Relationship of maxillary length to standard length. d. Relationship of snout length to standard length.

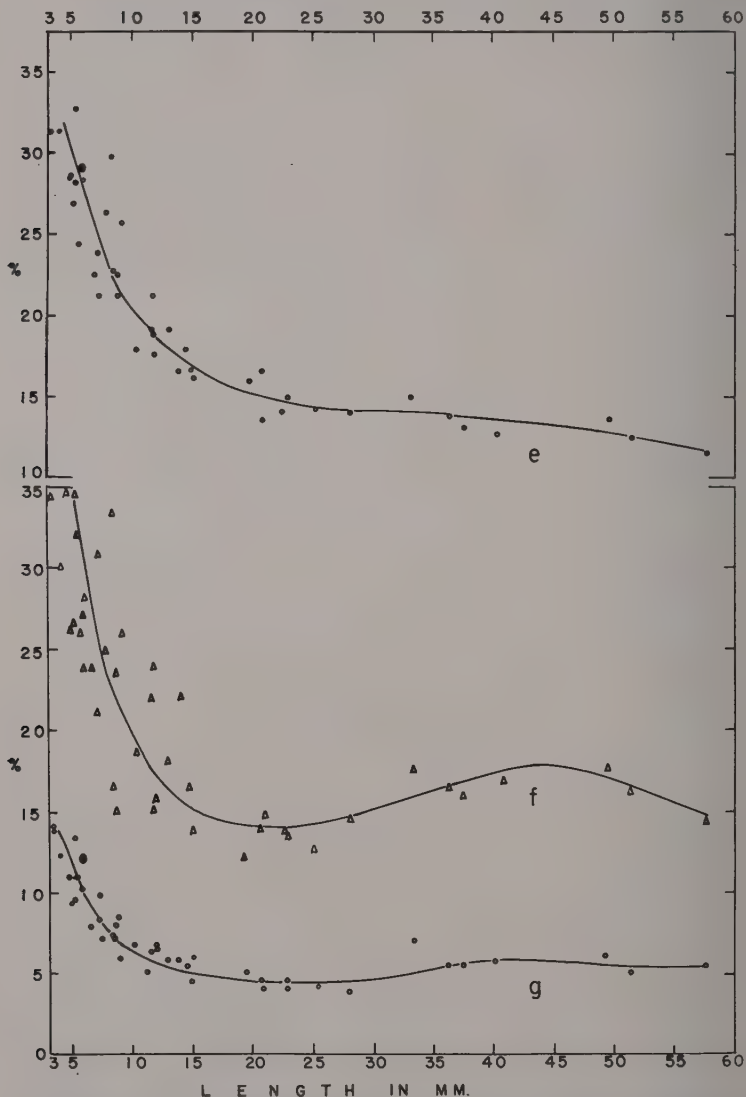


FIGURE 5. *Bregmaceros atlanticus* Goode and Bean. Change of bodily proportions during growth. e. Relationship of pre-cephalic length to standard length; f. Relationship of greatest depth to standard length; g. Relationship of orbit diameter to standard length.

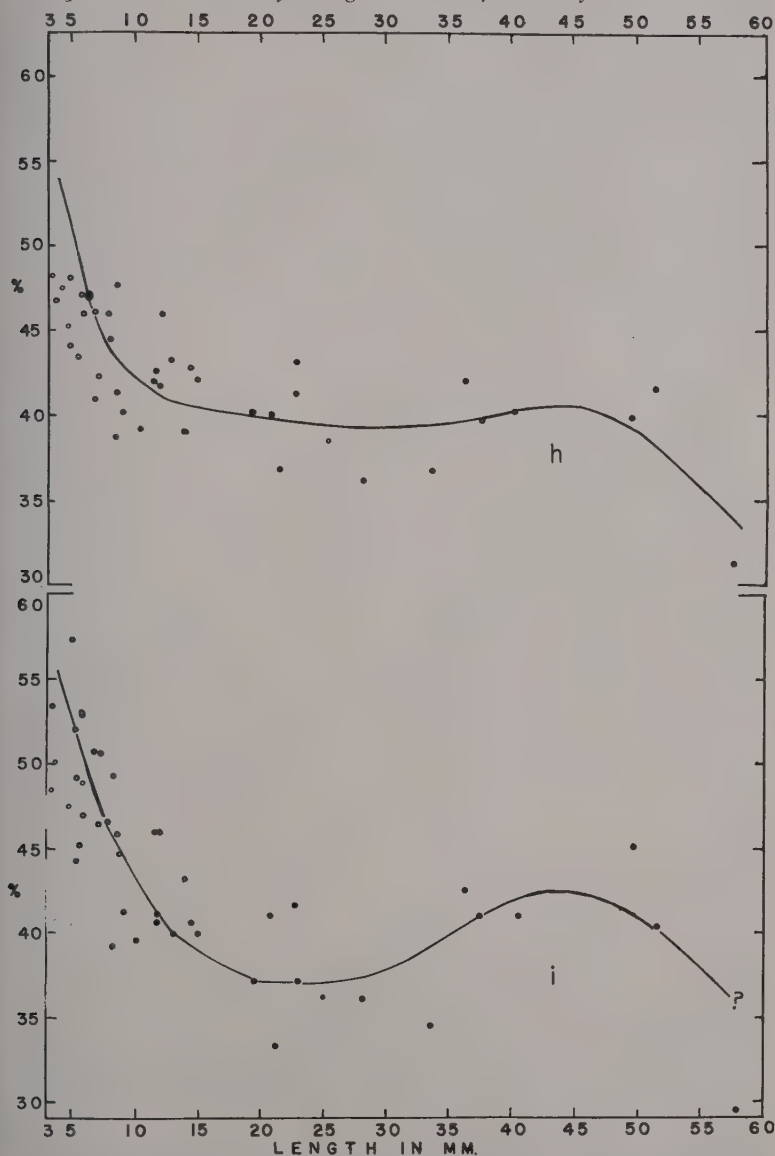


FIGURE 6. *Bregmaceros atlanticus* Goode and Bean. Change of bodily proportions during growth. h. Relationship of pre-dorsal length to standard length; i. Relationship of pre-anal length to standard length.

is located above the posterior margin of the orbit. The dorsal ray count is $15 + 12 + 16$; the anal, $15 + 9 + 20$. The anterior portions of the dorsal and anal fins are much higher than the posterior section. The longest ray of the first dorsal is 9.6 mm; second dorsal 3.5 mm; first anal, 10.5; second anal, 2.8 mm. The caudal fin is forked and has 30 rays. Fifteen rays comprise the pectoral fin. The longest of the three ventral rays measures 27.1 mm. Tufts are borne on the base of the innermost ventral ray. The head is small, having a rounded snout. The body is more robust than the juvenile.

General Growth.

The proportional growth curves (Figs. 4,5,6) show rather similar patterns. During the early postlarval stages, the various body measurements form a greater percentage of the standard length. These percentages gradually decrease to about 15.0 mm standard length, when they more or less level off, thus exhibiting a rather constant proportional growth. This pattern continues to approximately 30 mm when a rise in the growth curve takes place. This, however, does not occur in the cephalic appendage index. This rise continues to a peak which is reached between 40 and 45 mm standard length. A slight decrease, depending on the structure considered, is now observed until the largest specimen is reached. The level section of the curves, beginning around 15.0 mm, indicates the juvenile period. The rise in the curves probably signifies the young adult period, whereas the decline in the curves is the beginning of adulthood.

GENERAL BIOLOGY

Spawning.

Of the 47 specimens from the Straits of Florida studied in this work, no specimens were obtained in the months of March, October and November. This probably is due to insufficient sampling. The smallest postlarva measuring 3.1 mm was obtained in February. Postlarvae between 3.1 and 11.5 mm appeared in every month when this species was taken except in June. Since postlarvae of this species are well scattered throughout the year, it seems probable that *B. atlanticus* spawns in the Straits of Florida during most of the twelve month period. Such long term spawning is known to be common to many fish from tropical and subtropical waters.

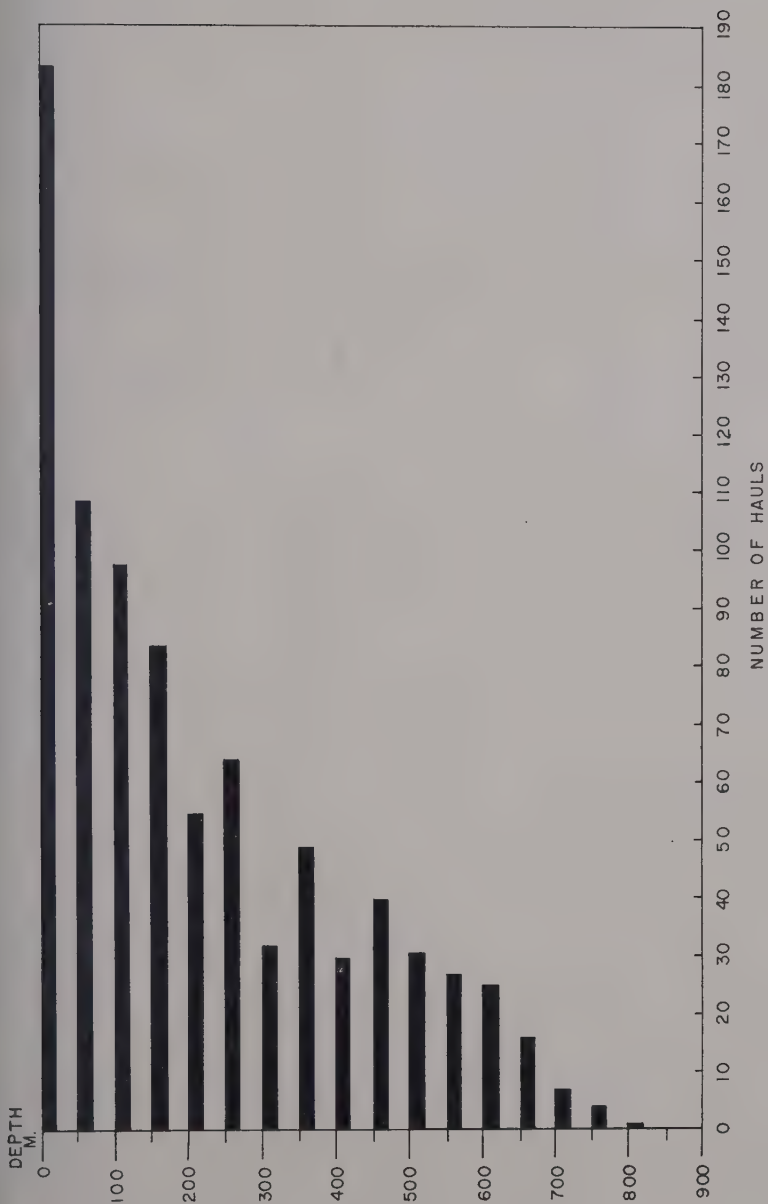


FIGURE 7. Depth distribution of all hauls taken by the Marine Laboratory. Depths are concentrated at 50 m. intervals.

Vertical distribution.

Stations were carried out for a period of slightly longer than five years. The YARA took 40 hauls, whereas the NG stations (excluding the YARA and including the ATLANTIS) comprised approximately 167 hauls and the SL approximately 675 hauls. Thirty-nine specimens of *B. atlanticus* or 0.044 specimens per haul were obtained, thus indicating that this species is uncommon in our area.

From the NG hauls (excluding the YARA) 16 specimens were obtained from 0-243 meters. The YARA took one adult specimen at

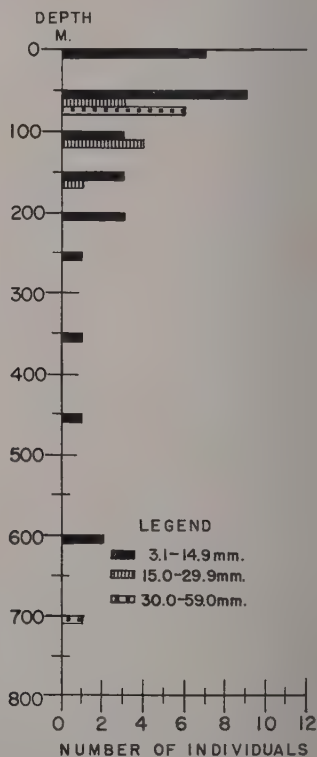
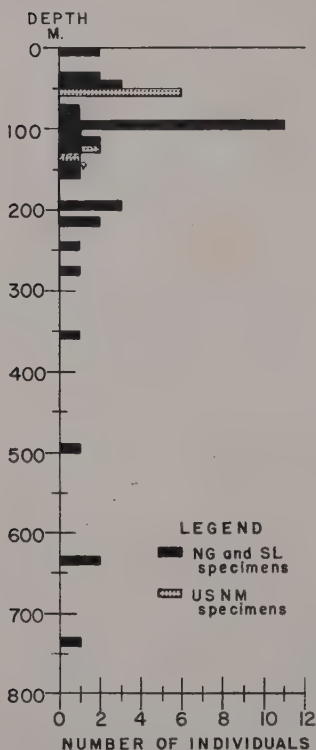


FIGURE 8. *Bregmaceros atlanticus* Goode and Bean. Depth distribution of specimens contained in this study. Figure on right concentrates all specimens of one size range found within a 50 m. range.

492 meters. At the inshore SL stations 5 specimens were obtained from the surface to 214 meters. Sixteen specimens were obtained between 91-731 meters from the SL stations occupied at the eastern edge of the Florida Current. The NG, YARA and SL hauls are shown in Fig. 8. It is seen in this graph that the majority of hauls were taken in the top 150 meters and because of this uneven samp-

TABLE 5

Stomach contents of 13 specimens of *Bregmaceros atlanticus* from the Straits of Florida.

Standard Length mm	Algae	Siphonophora	Chaetognatha	Copepoda	Pisces
5.85				1 cyclopoid fragment.	
6.70				1 cyclopoid fragment.	
8.1				3 calanoids, 2 cyclopoids.	
8.4				1 harpacta- coid fragment.	
10.2				1 fragment.	
11.5	1 fragment			1 calanoid, probably Euchaetidae; 1 calanoid fragment; 1 cyclopoid, probably <i>Corycella</i> <i>carinata</i> .	
11.9				1 calanoid fragment.	1 fish eye
13.0			1 fragment	1 cyclopoid fragment.	1 fish egg
14 (approx- imate)				2 calanoids, <i>Gaetanus</i> spp.; 2 calanoid fragments.	
15.0	few fragments			several fragments, possibly calanoid.	
22.9				calanoid fragments.	
25.4				1 fragment.	
28.1		1 <i>Dyphyes</i> sp.		calanoid fragment	

ling it is not possible to get an accurate picture of the vertical distribution of this fish. It would appear, however, that the majority of these fish occur in the upper 300 meters of the Florida Current and that only occasional individuals are found below this depth (Fig.8)

The waters sampled in this survey included the following ranges: salinity 34.96 - 36.82‰; temperature, 7 - 30°C; depth 0 - 823 meters; and illumination from almost none to about 1% of full sunlight. Table 5 gives these values for each of the specimens obtained, and from this it may be seen that *B. atlanticus* occupies nearly the full range found in this area.

Food.

Lebour (1919-22a), G. Voss (1953) and N. Voss (1954) have stated that a major component of larval fish food was copepod material, and this was also found to be true for *B. atlanticus*. All of the stomach contents of NG and SL specimens were studied, but only those having recognizable contents are listed in Table 5. From these data it was found that this fish feeds mainly upon copepods throughout the postlarval stages, and continues to feed upon them during the juvenile period. At 11.5 mm, the presence of algal filament suggests that the fish is now feeding upon larger objects. This is substantiated by the presence of a small fish eye in the stomach of the 11.9 mm fish, a fish egg and a chaetognath in the 13.0 mm specimen and a siphonophore in the 28.1 mm specimen.

SUMMARY

1. Forty-eight specimens of *Bregmaceros atlanticus* ranging from 3.1 to 57.8 mm standard length are described from the Straits of Florida and 10 specimens are illustrated.
2. Vertical distribution and spawning are discussed. From the evidence at hand it is considered that the majority of these fish live within the upper 300 meters in the Florida Current. Since early stages were found throughout the year, it is thought that this species spawns either the year around or over a long period of time.
3. From an examination of the stomach contents it was found that the majority of the food of the postlarvae and juveniles consists of copepods.

4. Bodily proportions, fin counts and length of longest fin rays are tabulated. The proportional growth curves show two peaks, one during the early postlarval period, the other probably during the young adult period.
5. All measurements, counts and data are given.

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The scope of the bibliography is limited in general to the area which includes the southeastern United States, the Gulf of Mexico, and the Caribbean, but papers of more general interest may be listed in cases where they have some special significance to the area.

The degree of comprehensiveness of the bibliography is to a large extent dependent upon the cooperation of workers in the Marine Sciences of this area. *It is therefore hoped that individuals and organizations will aid by sending copies of all relevant publications to the Editor.* Any omissions brought to the attention of the Editor will be included in subsequent issues.

It has been found convenient to use a modification of the classification used by the Journal du Conseil Bibliography for present purposes.

The Editorial staff wishes to acknowledge the valuable assistance given by a number of investigators in compiling the bibliography.

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